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THE USE OF ARTIFICIAL HEAT IN CURING CIGAR-LEAF TOBACCO.

INTRODUCTION.

The term "curing," as applied to tobacco, is sometimes used to include all of the processes to which the leaf is subjected after it has been harvested in preparing it for the manufacturer. There are thus included three more or less distinct processes, namely, the curing proper (frequently spoken of as "barn curing"), the fermentation process, and the aging process. The term as used in this article relates only to the first-mentioned process, in which the tobacco is prepared for fermentation.

In general, it can be said that the cigar-tobacco industry has reached a high plane of development in this country. In some sections at least, highly intensive methods are applied, the soil is heavily fertilized, the most approved cultural methods are used, and the growing crop from beginning to end receives the closest attention. Nevertheless, the methods of curing this type of leaf now in use must be regarded as crude when compared with those followed with some other types, notably the bright flue-cured tobaccos, notwithstanding the fact that with this latter type the general cultural methods are far from satisfactory. It is true that great progress has been made in the construction of barns for curing cigar leaf and many of those now in use in the wrapper-growing sections are models of perfection, but the method of curing which has been in almost universal use in sections growing cigar tobacco is air curing; that is, no artificial heat is used during the progress of the process. As a result the prevailing conditions in the curing barn are more or less subject to all the variations of the outside weather conditions and good curing is largely a matter of chance. Furthermore, the fact that there has been no satisfactory means of controlling the conditions in the curing barn has made it impossible for growers to make much progress in learning just what these conditions should be in order to secure the best results in curing.

The growers of western Florida have long followed the practice of utilizing open fires made on the floor of the barn for reducing the excessive moisture during wet or cloudy weather. This procedure, which has been more recently applied in connection with the growing of wrapper leaf under artificial shade, effectually prevents injury from the disease known as pole-sweat. Charcoal and well-seasoned wood are used as fuel, the fires being so managed as to produce as little smoke as possible. More recently open charcoal fires have come into extensive use in the Connecticut Valley in connection with the shade-tobacco industry, having been introduced by Mr. M. L. Floyd, of the Connecticut Tobacco Corporation. With these exceptions, however, it is only in rare instances that artificial heat is resorted to in curing cigar tobaccos.

CHANGES IN THE PROPERTIES AND COMPOSITION OF THE TOBACCO LEAF WHILE CURING.

That the properties of the tobacco leaf are greatly changed in the curing is well known to every grower, but the changes in composition which thus alter these properties and the necessary conditions for bringing about these changes are little understood. The leaf when harvested contains from 70 to 80 per cent of water, the greater portion of which is lost by evaporation during the curing. Nevertheless, curing involves much more than the mere drying of the leaf, for a leaf can be completely dried in a few minutes by applying sufficient heat and such a leaf does not show the properties of cured tobacco. In addition to the loss of water there is a marked loss in weight of other constituents of the leaf, usually amounting to 15 to 30 per cent of the weight of the cured product. Thus, a hundred pounds of green tobacco, containing, say, 75 pounds of water, will lose 4 to 7 pounds of dry matter in curing, in addition to losing more than 70 pounds of the water.

It is not necessary to enter into a consideration of the exact character of the changes involved in the loss of dry matter, but it can be easily demonstrated that these changes are dependent on the activities of the living cells of the leaf. If a green leaf be killed with chloroform, heat, or other means, such a leaf can not be cured. Curing, in fact, consists essentially in subjecting the living leaf cells to a process of gradual starvation under proper conditions. The loss in dry matter represents largely the material consumed by the cells in an effort to maintain life as long as possible and is analogous to the loss in weight of animals undergoing starvation. The evidence of these changes in composition brought about by the starvation and final death of the leaf tissue consists in the change of the green color to yellow and, finally, to brown, the change in texture and the development of elasticity, and other properties of cured tobacco.

THE NECESSARY CONDITIONS FOR GOOD CURING.

It is quite possible to dry the tobacco leaf without curing it, and it is also largely possible to cure the leaf without drying it. The two processes may or may not go hand in hand, depending on whether the existing conditions favor both processes. In practice the problem is to dry the leaf under such conditions as will best develop the desirable qualities of cured tobacco. It is to be remembered that if the living cells of the leaf are killed prematurely the curing is stopped once for all, although the drying may continue. Under ordinary conditions the leaf is killed by the loss of water, so it is essential that too rapid drying be avoided in order to afford an opportunity for the curing changes to take place. On the other hand, if the drying is too slow or is delayed too long the curing proceeds too far. The rate of drying is therefore one of the principal factors in good curing.

In addition to loss of water, the leaf cells may also be prematurely killed by excessively low or high temperatures or by mechanical injury, such as bruising the tissue in harvesting. No portion of a leaf which is prematurely killed by these or other means can be successfully cured. It follows that tobacco which is subjected to frost, freezing temperatures, or too high temperatures when artificial heat is applied, especially in the first stages, can not be properly cured.

Aside from the premature killing of the leaf tissue by extremes of heat or cold, the temperature plays a very important part in affecting the rate of curing. The curing proceeds very slowly or is stopped completely at temperatures below 60° F., while the drying may go on rapidly if the air entering the barn is dry; in other words, the leaf under these conditions is likely to dry without curing. On the other hand, curing proceeds very rapidly at 80° to 100° F., while the rate of drying can be controlled by regulating the humidity in the barn.

It will thus be seen that the necessary conditions for good curing are that the tobacco be placed in the barn in sound condition, that the temperature be kept sufficiently high to allow the curing changes to proceed normally, and that the rate of drying be controlled by regulating the humidity so as to avoid either too rapid or too slow drying. The matter of properly regulating the humidity in the curing barn is discussed in the succeeding paragraphs.

POLE-SWEAT, OR POLE-BURN.

Pole-sweat, or pole-burn, which is so well known in those tobacco-producing sections where artificial heat is not used in curing, is one of the results of too slow drying in the more advanced stage of curing. Pole-sweat is nothing more than the rotting or decay of the leaf and is analogous to the ordinary decay of organic matter of either animal or vegetable origin. It is important to understand this fact fully, for it renders it an easy matter to recognize the stage of the curing when pole-sweat is to be looked for and points clearly to the proper remedy. The decay of the leaf is due to micro-organisms, or "germs," which are active only at moderate temperatures and in the presence of an abundance of moisture. There will be little or no pole-sweat so long as the temperature remains below 60° F. or the relative humidity is less than 85 per cent.

It is also important to remember that these organisms feed only on dead or dying tissue. So long as the leaf tissue remains alive there can be no pole-sweat. Under ordinary conditions the appearance of the yellow color on the leaf indicates that the cells are reaching the dying stage; hence, this is the stage where pole-sweat is to be expected. It is sure to develop if the temperature is warm and if the humidity in the barn is high. It will be seen that the most favorable conditions for curing are those which lead to pole-sweat, but it is also true that the real curing is practically completed when the stage for pole-sweat is reached, and these facts open the way for a simple remedy against the disease.

Most growers are familiar with the so-called "strutting" of the leaf as a forerunner of pole-sweat, which is a stiffening of the midrib and veins, causing the previously wilted leaf to stand out somewhat like an opened umbrella. This strutting has no direct connection with pole-sweat except that both are due to the same cause, namely, excessive humidity.

Stem-rot—that is, decay of the midrib—is also likely to appear in the later stages of the curing when the drying is checked by excessive humidity. This trouble is more common when the tobacco is harvested by picking the leaves from the stalk. In the later stages of curing, after the leaf has turned brown, damage may result from drops of moisture collecting on the leaf when the drying is checked, thereby causing discoloration, even though pole-sweat does not develop.

HOW TO PREVENT POLE-SWEAT.

While it is true that pole-sweat is held in check by temperatures below 60° F., it is to be remembered that the curing is also stopped at low temperatures, while the drying of the leaf may continue. The only practicable remedy lies in the proper control of the humidity in the barn; in other words, there must be adequate means of removing the excessive moisture during periods of wet weather.

Many growers have an impression that ventilation is effective in controlling this disease, but it can be easily seen that if the outside air is saturated with moisture ventilation alone, however thorough it may be, can not possibly reduce the moisture in the barn. Moreover, the degree of crowding together of the tobacco in the barn has an influence only in so far as this affects the moisture of the air, and a single leaf of tobacco placed in the barn will rot the same as if the barn were completely filled, provided the temperature and moisture conditions favor pole-sweat. To reduce the moisture in the barn in wet weather the relative humidity of the air in contact with the tobacco must be reduced, and the only practicable means of accomplishing this is by the use of artificial heat combined with properly regulated ventilation. The capacity of the air[1] for holding moisture is greatly influenced by the temperature. For each increase of temperature of 18 or 20 degrees the capacity is doubled; so that, for example, if the temperature of a given volume of saturated air is raised from 50° to 70° F., the relative humidity drops from 100 per cent to 50 per cent. It will be seen, therefore, that if sufficient heat is applied to raise the temperature in the barn 15 or 20 degrees, and if the air is constantly renewed by ventilation, the relative humidity will be kept down to only 50 or 60 per cent. Under these conditions the tobacco will dry even more rapidly than is the case on a warm, bright sunshiny day.

To so regulate the temperature and ventilation as to avoid pole-sweat and at the same time insure the best possible curing is a matter for which definite instructions can not be given, for the reason that so much depends on the varying outside weather conditions and on the character and quantity of the tobacco in the barn. Our experiments in the Connecticut Valley have shown conclusively, however, that pole-sweat can be easily and completely controlled by the combined use of heat and ventilation, no matter how unfavorable the weather may be, and it is only a matter of experience to determine the quantity of heat and the amount of ventilation required in any given case. To be assured of success under all conditions means must be available for raising the temperature in the barn, which must be reasonably tight, 15 to 20 degrees above the outside temperature when moderate ventilation is used. Where the heat is applied before pole-sweat begins it will usually be necessary to use only moderate amounts if the heating is continued until the tobacco has passed the danger point, whereas if the disease has already gained headway more drastic heating is required to check it promptly.

The mistake must not be made of applying too little heat or applying it for an insufficient length of time, for this will only aggravate the trouble. In no case where there is real danger of pole-sweat should the temperature in the barn be allowed to remain less than 10 to 12 degrees above that of the outside air, and moderate ventilation is likewise essential. The condition of the tobacco is the proper guide in all cases, and it is important to examine the leaf at intervals in all parts of the barn, and particularly in the upper tiers. The heated air tends to rise, and sufficient heat must be used to reach the top of the barn; otherwise the moisture from the tobacco in the lower tiers is merely carried upward and deposited on the cooler tobacco nearer the top.

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[1] It should be stated here, once for all, that, strictly speaking, the air can not be considered as having capacity for moisture, for the water vapor is in reality merely mixed with the air. It would be more correct to speak of a given space as being saturated with moisture, but the common phraseology is so firmly established and so much more readily comprehended that for our purposes it seems desirable to retain it.

THE EFFECT OF HEAT APPLIED DURING THE CURING PROCESS ON THE QUALITY OF TOBACCO.

In considering the use of artificial heat in curing cigar tobacco the question naturally arises as to the effect of the heat on the quality of the cured leaf. As a matter of fact, it is quite possible so to apply the heat as to produce no artificial condition; that is, it may be applied only when the weather is unfavorable, and in such a way as to create those temperature and moisture conditions which would prevail in the barn when the weather is just right for curing. In this case the principal use of the heat would be to prevent pole-sweat, and there is no reason to suppose that the result of the curing would be different from that obtained in favorable weather without the use of artificial heat.

On the other hand, the curing may be forced by the use of heat so as to hasten the process and materially affect the quality of the cured leaf. Bearing in mind that the rate of drying and the rate of curing may or may not go hand in hand, it is plain that uniformly satisfactory results in tobacco curing can never be assured until efficient methods of regulating the temperature and moisture in the barn are followed. Artificial heat not only furnishes a means of securing the most favorable temperatures for curing, but when combined with ventilation also constitutes the only practicable means of controlling the humidity.

The rate of curing greatly increases with a rise in temperature, and in general more thorough curing is obtained at higher temperatures, provided the leaf is not dried too rapidly. It follows that artificial heat when properly applied is highly favorable to the quality of cigar tobacco, for thorough barn curing is essential to the best development of flavor, aroma, and elasticity and, to a lesser degree, of color in the sweating or fermenting process.

Artificial heat probably shows the greatest effect on the color of the cured leaf. Heat in the presence of sufficient moisture greatly hastens the rate of curing, but when used in conjunction with ventilation it also greatly increases the rate of drying. At given temperatures the extent of the changes in color occurring during the curing are controlled by the amount of moisture in the leaf, so that the use of heat and ventilation combined makes it possible to control to a certain extent the colors obtained. We have found in the course of our experiments that not only the depth of the color, but also its character, can be largely controlled by regulating the temperature and ventilation. Under the present method of curing cigar-wrapper tobacco, particularly when the leaf is cured on the stalk, the final color of the bright wrappers is normally a clear cinnamon brown, free from any greenish cast, but generally showing more or less tendency toward a reddish cast. The present demand is for a wrapper of rather dull finish, showing the lighter shades of brown overlaid with a faint olive but absolutely free from red. The recent rapid development in the Connecticut Valley of the method of harvesting by picking the leaves from the plant is due primarily to this demand for a wrapper of "Cuban finish." It has been demonstrated that artificial heat is an important factor in obtaining the best curing with this type of leaf.

FORCING THE CURE BY THE USE OF ARTIFICIAL HEAT.

The two most important reasons why artificial heat should be used in curing practically all tobaccos are that (1) this affords the only practicable means of preventing the decay of the leaf caused by excessive moisture during wet weather and (2) tobacco does not cure properly at low temperatures, however favorable the weather may be otherwise, a fact of special importance in northern tobacco districts. In the case of cigar-wrapper leaf another important consideration is that proper control of the moisture in the barn, which can only be accomplished by the use of heat combined with ventilation, is the most efficient means of securing desirable colors in the cured product. Where no heat is used it frequently happens that even after the curing is largely completed wet periods of weather bring the tobacco into such moist condition that the color is greatly darkened and the quality of the tobacco otherwise injured, while if cold weather prevails during the curing the leaf simply dries without otherwise developing the desired properties of cured tobacco. The curing of cigar tobaccos can never be placed on a satisfactory basis until the process has been rendered largely independent of weather conditions by the combined use of artificial heat and ventilation.

During the first stage of the curing, in which the yellow color develops, the principal value of the heat is to maintain a favorable temperature in the barn, and during this period care must be taken to avoid too rapid drying. It is evident that the barn must be reasonably tight, so as to prevent the rapid escape of the heat and moisture. On the other hand, the barn must have proper means of ventilation during wet weather, otherwise the drying will be checked and there will be danger of pole-sweat when the second stage of the curing is reached. If the outside temperature is below 60° F., heat should be applied; if the weather is clear, little, if any, ventilation is needed, while in wet weather more ventilation is necessary. The aim should be to keep the temperature in the barn above 70° F. and to regulate the ventilation so that the tobacco will dry slowly until it is pretty well yellowed. The leaf will cure satisfactorily at any temperature between 70° and 100° F., and the exact temperature to be maintained in the barn will depend on outside weather conditions. To prevent too rapid drying in cold, dry weather, even with the minimum amount of ventilation, the inside temperature should not be much more than 10 or 12 degrees above that of the outside air, while in wet weather a difference in the inside and outside temperatures of about 15 degrees is desirable, the ventilation also being increased.

With favorable temperatures the necessary changes effected in the curing proceed much faster than is commonly supposed, even though this is not apparent to the eye, so that when heat is applied, if the leaf does not become dry during, say, the first 48 hours, there is no danger of injuring the color thereafter by rapid drying. Under these conditions the green color left in the leaf disappears as soon as the cured tobacco comes into case a few times; in fact, in our experiments the best colors have been obtained from tobacco which was still quite green when the curing proper had been completed.

After the first stage of the curing has been completed—that is, when the leaf has yellowed sufficiently—whether or not the further use of heat is desirable depends mainly on the prevailing weather as to humidity. This is the period for pole-sweat, and if there is much damp weather the heating will need to be continued, while with favorable weather the curing can be completed without the further use of heat. In any event, however, the tobacco at this stage should be allowed to soften well before proceeding with the drying, and it is well to allow the leaf to come into good case from time to time until the midrib is cured. If, because of lack of barn room or other reasons, it is desired to hasten the second stage of the curing, heat can be freely used without fear of injuring the quality of the tobacco.

While it is true that the occasional softening of the tobacco during the second stage of the curing greatly improves its appearance, growers as a rule do not fully appreciate the serious injury to the color caused by allowing the cured tobacco to become too damp. Each time a cured leaf becomes damp the color is not only darkened, but loses in clearness and, besides, the tobacco undergoes a sort of cold sweat which interferes with its normal fermentation in the packing house. This injury can be easily avoided by drying out the tobacco with artificial heat during wet or damp weather.

The suggestions here outlined regarding the use of artificial heat in curing have been worked out by experiments with wrapper leaf harvested by picking the leaves from the stalk, but the same principles can be applied to curing on the stalk, the main difference being that the curing will necessarily require more time. In our experience with picked tobacco, as has already been stated, in addition to avoiding direct injury to the quality of the leaf from unfavorable weather conditions, it has been found that the use of artificial heat gives the desired brown color, free from red and of dull finish.

METHODS OF APPLYING ARTIFICIAL HEAT.

We have pointed out the necessity of having available some suitable means of applying artificial heat, in order to control the temperature and moisture conditions in the barn, if the best results in curing are to be obtained. This brings us to a consideration of practical methods of applying heat and the requirements which these methods must meet. In cold, dry weather the curing ceases but the drying continues, while in warm, wet weather the curing proceeds rapidly and the leaf may even decay because the drying is stopped. A practical heating system must, therefore, be capable of controlling both the temperature and humidity so as to avoid these extremes.

No heating system will give satisfactory results in a barn which is not reasonably tight, for the temperature in such a barn can not be raised sufficiently without drying the tobacco too rapidly. On the other hand, a system of ventilators which can be opened and closed at will is necessary for the removal of the excessive moisture in the barn in wet weather. If there is no ventilation the air in the barn soon becomes saturated, and heat alone is of little or no value in this case. When artificial heat is used it is not desirable in filling the barn with tobacco to leave open spaces or vents from top to bottom, for these merely serve as channels for the escape of the heat to the top of the barn, while to be effective it must be forced to pass through the tobacco.

The heating system must have sufficient capacity. A little heat is frequently worse than none, particularly in the control of pole-sweat. Experience has shown that a satisfactory system must be capable of maintaining the temperature in the barn from 15 to 20 degrees higher than that of the outside air when moderate ventilation is used. It is only necessary to maintain this difference in temperature, however, when there is danger from pole-sweat, and under ordinary conditions a difference of 10 or 12 degrees between the inside and outside air is sufficient. The heat must be applied at the bottom of the barn and must be evenly distributed in order that, so far as possible, all of the tobacco may receive the same amount.

As is well known, artificial heat has long been used in curing certain types of export and manufacturing tobaccos. There are essentially two methods of applying the heat. In the case of the so-called dark fire-cured export tobacco open fires are made on the floor of the barn and the smoke is allowed to pass up through the tobacco, thereby imparting a characteristic odor and taste to the leaf. No heat is applied for the first few days and thereafter the fires are maintained only at intervals, so that the tobacco is only partially cured with artificial heat. In the case of flue-cured manufacturing tobacco, the heat is introduced by means of furnaces fitted with a system of flues through which the heat is distributed. This method differs from fire curing in that the smoke does not come in contact with the tobacco and the heat is applied continuously throughout the curing. The process is completed in from three to five days. In flue curing, the temperature can be controlled with exactness, and this is decidedly the most perfect system of curing now in use. In both flue curing and fire curing wood is the fuel used.

It has already been stated that open fires have long been used in curing cigar tobacco in western Florida, and both wood and charcoal have been used as fuel. In curing shade-grown cigar-wrapper leaf in the Connecticut Valley open charcoal fires are quite generally used. The application of open fires and of heating by means of flues is considered in the following paragraphs.

THE USE OF CHARCOAL IN CURING.

The evident points in favor of open fires as a source of heat in curing are simplicity and cheapness, provided the fuel used is not expensive. Where wood can be used this is the cheapest method of applying heat, since wood is in most cases still a comparatively cheap fuel and open fires require almost no special equipment. Charcoal is generally preferred for curing cigar tobacco, however, for the reason that it burns with very little smoke. On the other hand, charcoal is one of the most expensive of fuels and the supply is limited and uncertain. It is an established fact that even cigar-wrapper leaf is not injured by small quantities of smoke, so that thoroughly seasoned wood, corncobs, and similar materials which burn with but little smoke can be used successfully in an emergency. Of course, any material which burns with dense smoke will cause serious damage by discoloring the leaf with soot. Coal and coke can not be used for open fires because of injurious gases, mainly sulphur dioxid, formed in combustion.

One of the principal difficulties to be met in using open fires is in securing an even distribution of the heat. The tobacco hanging directly over the fires will be overheated, while that between the fires is not likely to receive enough heat. Evidently a large number of small fires is better than a few larger fires, and they should not be more than 6 or 8 feet apart each way. It will be seen at once, however, that the labor required in taking care of the larger number of fires will be greatly increased. The small fires require close attention to keep them going and to avoid the danger of burning the barn. If the bottom tier of the barn is filled the tobacco hangs so near the ground that the fires are not easily accessible. In any case the tobacco hanging immediately above the spots chosen for the fires must be removed before these are started. Small heaters are occasionally used for burning charcoal, but these are of doubtful value except that they lessen the danger of accidental fires, and the same may be said of small pits dug in the floor of the barn, which have been used by some. Deflectors of various kinds are frequently suspended above the fires to secure a better distribution of the heat, and these are serviceable, but less so when constructed of metal, because they then transmit the heat very readily. They are most efficient when flat or having the shape of an inverted cone.

Open charcoal fires have thus far been used mainly in curing shade-grown tobacco, all of which is harvested by picking the leaves from the stalk. The method commonly used is to keep the fires going for about three days or until the leaf is pretty well yellowed, after which no heat is used except to prevent damage from pole-sweat in wet weather. During this period the approximate range of temperature in the barn is from 80° to 100° F., depending, of course, on the outside weather conditions. As a rule, the barns are kept tightly closed during the firing to prevent the tobacco from drying too rapidly. The roof of the barn being covered with shingles and therefore affording considerable ventilation and this class of tobacco being very light in body make it possible to dispense with ventilators on the peak, although these are undoubtedly very desirable in northern latitudes, as, for example, in the Connecticut Valley. The quantity of charcoal required for curing shade-grown tobacco will naturally depend very much on weather conditions, but with normal seasons there will usually be required from 200 to 300 bushels for a barn holding 5 acres of tobacco. With unfavorable weather conditions much larger quantities will be needed.

For curing ordinary picked tobacco, particularly the broadleaf, which is especially liable to develop pole-sweat, much more fuel will be required because of the greatly increased amount of water to be removed from the barn. For curing on the stalk still more heat will be required if the curing is to be forced, as is done with the shade-grown leaf, and it is doubtful whether charcoal could be used except at prohibitive cost unless the heat is employed merely to temporarily ward off pole-sweat.

THE USE OF FLUES IN CURING.

Because of the difficulties attending the use of charcoal fires for forcing the cure of cigar tobaccos, more particularly the ordinary picked and stalk-cured types, which have been pointed out previously, experiments have been conducted during the past few years in the Connecticut Valley with a view to devising a more economical and satisfactory method of applying heat. The possibilities of steam heating were first investigated, but it was found that such a system is impracticable because of its cost. Attention was next turned to the use of flues, such as are employed with other types of tobacco, and with much better success.

As shown in figure 1, the heating system used in flue-curing districts consists of sheet-iron pipes 10 to 15 inches in diameter, leading from furnaces placed at one end of the barn. The flues extend across the barn and in returning pass out through the side of the barn, with a short smokestack at the end. It will be observed that the flue-curing barns are quite small, so that the heat is uniformly distributed. The aim of our experiments has been so to modify this method of heating as to make it applicable to the curing of cigar tobacco.

One of the first changes necessary in adapting this system to cigar leaf is that the furnaces shall be placed wholly on the inside of the barn. This prevents unnecessary loss of heat, greatly reduces the danger of setting fire to the barn, and protects the fire box from being flooded during rainy weather. Since the furnaces need to be set up permanently, they must be placed in the ground in order that they shall not interfere with the work of handling the tobacco and also that the necessary grade can be given the flues.

Since the high temperatures used in the flue-curing districts are not needed in curing cigar tobacco, the flues should not be so large. Experience has shown that those having a diameter of 8 inches are quite satisfactory. In the flue-curing districts the flues are made of light-weight black sheet iron and will last for many years, but in the Connecticut Valley it has been found that such flues will scarcely last more than one season. Galvanized iron of No. 24 gauge is recommended as a satisfactory material for constructing durable flues. Flues of this material will weigh something less than 3 pounds per foot. To facilitate setting up the flues and to avoid the danger of fire from loose joints the short pieces of pipe should be riveted together into long sections. It is important to have the open joints of these long sections made so that they can be easily connected, and they should be provided with "boot straps" for tying together securely with wire. The joints ordinarily made by the manufacturer fit so tightly that it requires much time and patience to put them together.

Thus far wood is the only fuel which has been found suitable for heating the flues, and the furnaces have been designed more particularly for this fuel. In the system which has been developed the 16-foot sections formed by posts, frames, and girders set up across the barn and known as "bents," are taken as the unit, so that each

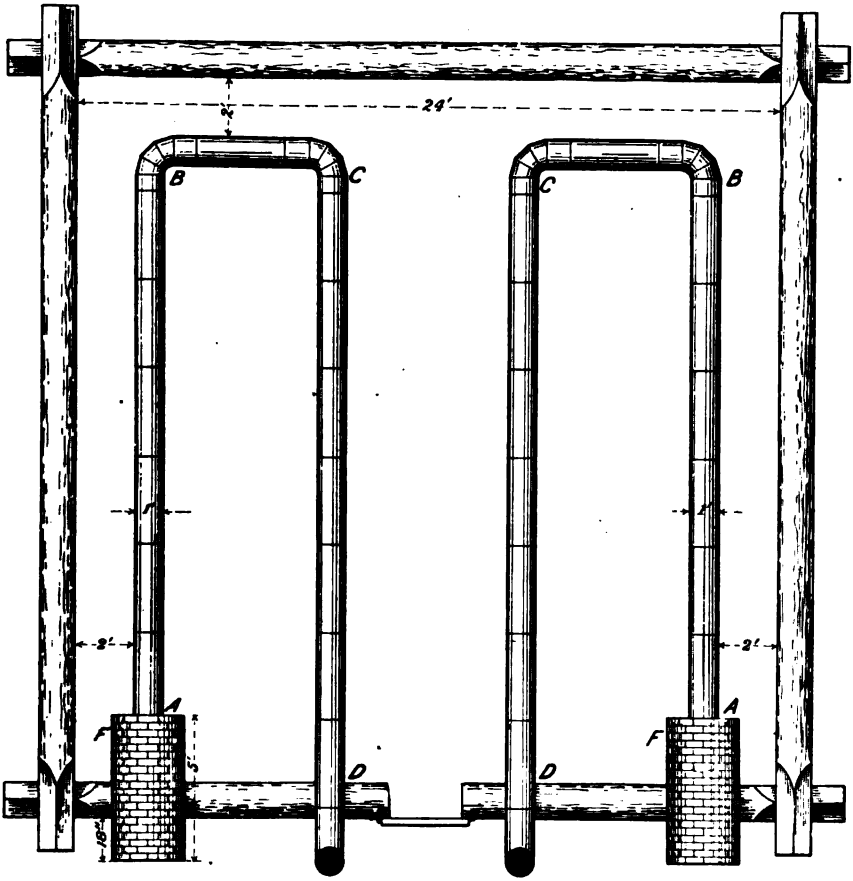

FIG. 1.—Sketch showing the arrangement of furnaces and flues in a barn adapted for curing yellow tobacco: *F*, *F*, Brick furnaces; *A*, *B*, *C*, *D*, sheet-iron flues.

section, or bent, requires an independent furnace and set of flues. The furnace, which is set in the ground, should be not less than 5 feet long and about 16 inches wide, inside measurement. The top should slope upward from about 16 inches at the front to, say, 26 inches at the back. The sides and the closed end may be made by laying a single thickness of brick without cement of any kind along the sides of the pit dug for the purpose, sheet iron fitted with a collar for receiving the end of the flue and covered with 2 or 3 inches of soil serving as a top. Such a furnace, however, is not durable and is comparatively expensive.

A very cheap and desirable type of furnace, made of concrete cast in sections, is shown in figure 2. Sand and trap rock were used in casting these furnaces and the formula used was that ordinarily employed for mixing "strong" concrete. The top, sides, and end are all 4 inches thick and of the dimensions given in the preceding paragraph. The sides are cast with a 2 by 4 inch notch at the rear end for receiving the back. The top is reenforced with steel and is provided with an opening, tapering downward, 6 inches from one end for receiving the end of the flue. The top is cemented on at the time of setting up the furnace. The sections of the furnace are heavy, and should be cast in the barn in which they are to be used. If the sand and rock can be had near at hand a furnace of this type would cost only about $1.50, exclusive of labor. In tests during the past season these furnaces gave very satisfactory results, and there is reason to believe that if properly made they will prove very durable.

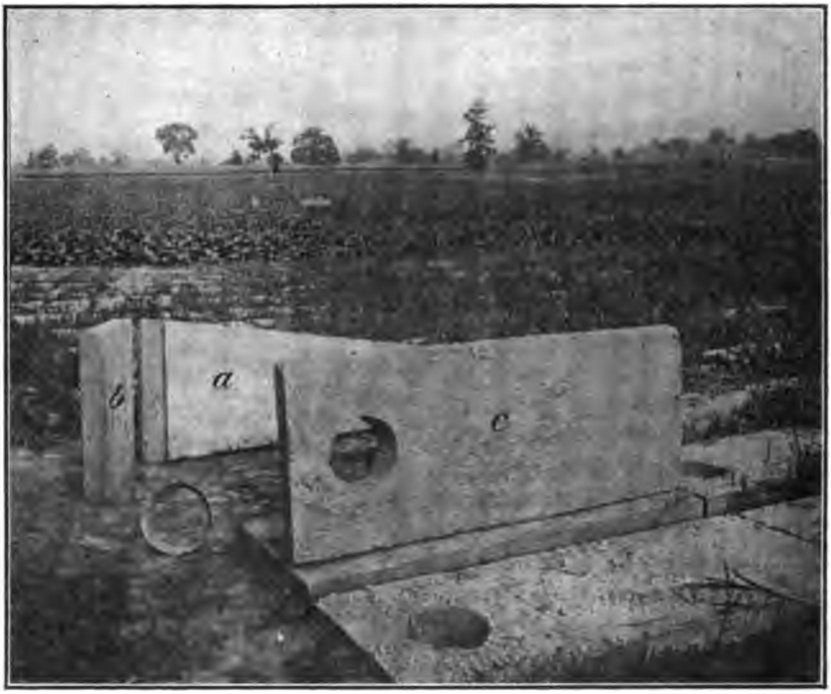

FIG. 2.—Type of concrete furnace, cast in sections, for use in applying artificial heat through flues, devised by W. S. Pinney, Suffield, Conn.: *a*, Side of furnace, with sloping upper edge and recess in rear end for receiving the end of furnace; *b*, *c*, top, with tapered opening at rear end for receiving end of flue.

In the system of heating which has been developed with the bent as the unit, figure 3 shows the best method which has been devised for setting up the flues. The furnaces may be made to run either lengthwise or crosswise of the barn. They are all placed on one side of the barn, preferably on the north or west side. To prevent the excessive radiation of heat from the front end of the furnace the lower portion of the opening should be kept closed. This can be conveniently done by means of a piece of L-shaped sheet iron, of the width of the furnace, which will close about one-half the mouth of the furnace. By closing the lower portion the air is forced to enter through the upper portion of the opening, which does not interfere with the draft but prevents the escape of heated air from this end of the furnace.

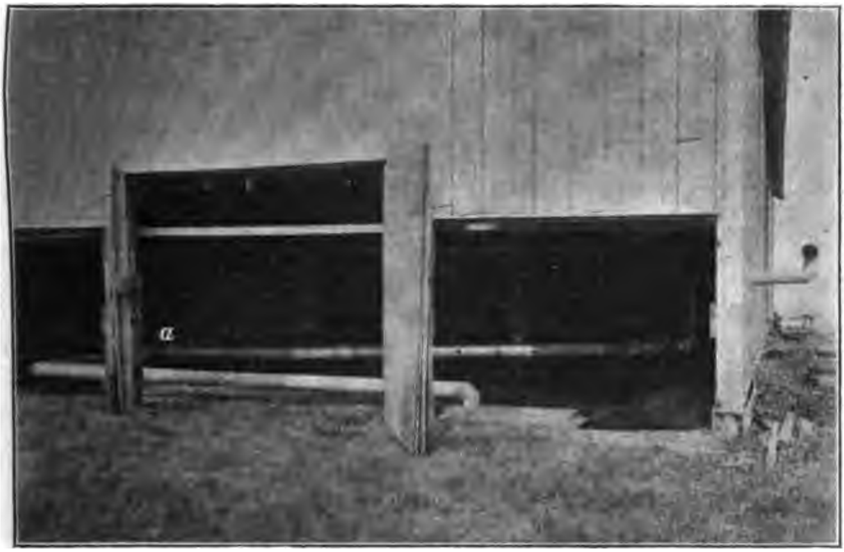

FIG. 3.—Furnace and flue in position. At *a*, a T-section may be inserted, the open end of which passes out of the side of the barn, thus preventing a back draft when the wind blows into the end of the flue. A separate furnace and set of flues, as shown, are required for each bent of the barn.

The first section of the flue running across the barn from the furnace can be riveted together into a single piece, while the return portion can be made of two sections, exclusive of the upright bend near the point of exit. This rise at the outer end of the flue is to facilitate passing from one furnace to the other and also to secure a better draft in the pipe. The elbow on the end is not essential, but is helpful in windy weather, as it can be turned so that the open end is away from the wind. The best method of supporting the flues is by means of a light-weight chain and small S-hooks suspended from the tier poles, making it possible to regulate quickly the grading of the flues. About 36 feet of chain are required for each bent.

The system set up as described works very satisfactorily, except when there is a strong wind blowing directly into the open end of the flue. In this case the flues can not be made to draw. This difficulty is overcome by using a T-section, fitted with a damper, for connecting the return portion of the flue with the end portion—that is, at the corner farthest removed from the furnace (see fig. 3, A). This section will automatically check the back draft caused by the wind blowing into the open end of the pipe by furnishing an exit for the surplus smoke. The end portion of the flue connecting the two runs across the barn can be riveted together into one section, including the elbow at one end and the T-piece at the other.

With a properly constructed barn this system of heating is easily capable of maintaining a temperature 20 degrees above that of the outside air. It is estimated that from 1 to 2 cords of wood will be required for curing an acre of picked tobacco. Some idea of the relative cost and heating value of wood as compared with charcoal can be had from the following data: The average weight per cord of wood of various kinds, such as oak, hickory, pine, chestnut, etc., is about 3,000 pounds, yielding about 32 bushels of charcoal, which weigh approximately 700 pounds. The quantity of heat obtained from 3 pounds of wood is approximately equal to that obtained from 2 pounds of charcoal, so that a cord of wood will yield about three times the quantity of heat obtained from the same quantity of wood after being converted into charcoal. The present price of charcoal in the Connecticut Valley is equivalent to a price of $12 to $15 per cord for wood. It is considered that the system of heating with flues which has been outlined will cost, complete, about $20 per bent, or, approximately, $35 per acre. The equipment with minor repairs will last many years, and it has been shown that it may pay for itself in a single season of bad curing weather.

It has been conclusively proved by Mr. W. S. Pinney and others through tests carried out on a large scale in the Connecticut Valley during the past two years that this system not only removes all danger from pole-sweat, but produces tobacco of the highest quality in all respects, particularly when applied to tobacco harvested by picking or priming the leaves. It is very probable that the method of constructing and arranging the furnaces and flues which has been described will be materially improved upon, and there would seem to be possibilities in developing a plan involving the use of one or more central smokestacks or chimneys extending through the roofs, into which the various flues can be led. What it is desired to emphasize more particularly is the fact that it has been convincingly demonstrated that the use of flues for applying artificial heat affords the best method yet devised for curing cigar tobacco, especially for curing the picked leaf.

In view of the fact that wood is not always easily obtainable it is highly desirable that some method of heating be devised whereby coal can be used, for this is a standard fuel which can be had in unlimited quantity. It seems possible that coal can be used for heating a system of flues if a forced draft is employed, but this would require some sort of motive power.

BARNS ADAPTED TO THE USE OF HEAT IN CURING.

It has already been pointed out that ventilation in conjunction with heat is required to control properly the humidity in the barn. The barns most used in curing shade-grown tobacco are high and have a steep shingle roof. Air can penetrate the shingle roof rather freely, which makes it possible to utilize charcoal fires without the use of a roof ventilator, but, nevertheless, the curing conditions could be better controlled with such a ventilator. In curing with flues, especially in the case of tobacco other than shade grown, the leaf of which is much larger and heavier in body, the roof ventilator is very important. Moreover, lower barns with flat roofs are much more desirable, for it is very difficult to force the heat through the green tobacco in high barns with steep roofs. Moderate-sized barns which can be filled in a day or two, so that the heat can be applied promptly, are preferred to larger ones. In the case of large barns, however, to fill which requires several days, temporary partitions can be put in at convenient intervals by tacking up strips of burlap on the cross framing. The burlap partitions, which are very effective in preventing the escape of the heat, make it possible to run the furnaces in one section while the next is being filled.

In figure 4 is shown a 7-bent barn with a low, flat roof of paper, designed by Mr. W. S. Pinney, of Suffield, Conn., which is especially adapted for curing the ordinary types of picked wrapper leaf. It will be noted that in addition to the regulation side ventilators a special ventilator extends along the peak of the roof, which opens on each side. The doors on either side can be opened or closed from the ground by means of ropes and pulleys. While heat is being applied all side ventilators are tightly closed, except the horizontal ventilator at the bottom, through which such air as is needed for ventilation is introduced. In operating the roof ventilator the principal point to be observed is to open only the side away from the wind. In dry weather comparatively little ventilation will be needed and frequently none at all, while in wet weather ample opportunity for the circulation of air must be given.

The aim should be to allow the air to enter the barn near the ground and, after being heated by coming in contact with the flues, to pass upward through the tobacco and finally to pass out through the roof ventilator. This is in accordance with natural laws regulating the circulation of air as affected by temperature. The sole object is to so regulate the heat and ventilation as to secure the proper temperature in the barn for curing and so to control the humidity that the tobacco will not be injured by drying either too rapidly or too slowly. We have here outlined a means for accomplishing this object, which makes it possible to cure cigar tobacco under uniformly favorable conditions regardless of the outside weather.

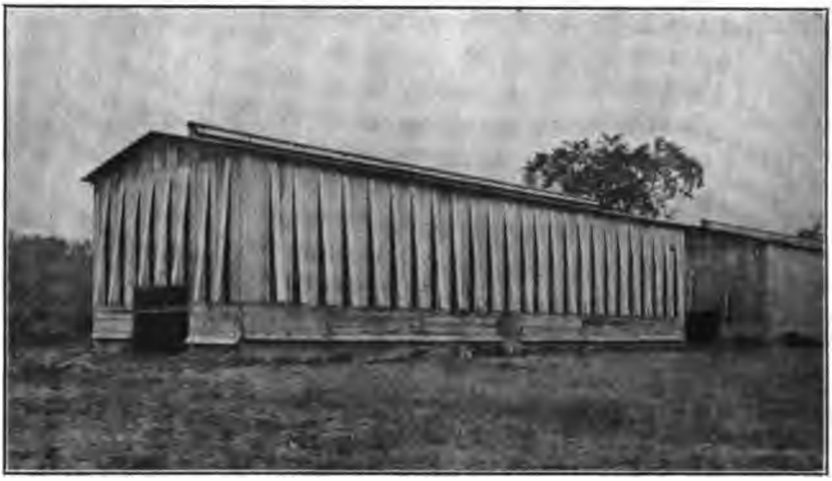

FIG. 4.—Moderate-sized barn with low, flat roof and ventilator extending along the peak of the roof, especially adapted for the use of artificial heat in curing.

SUMMARY.

Methods of curing have not kept pace with the advances made in other features of cigar-tobacco production and are still comparatively crude. Curing involves important changes in the composition of the leaf other than the loss of water, and a clear distinction is to be made between curing and mere drying. The process is dependent on the life activities of the leaf cells and is essentially a process of starvation.

To insure good curing, the leaf tissue must not be killed or injured by freezing or by bruising before being placed in the barn, the temperature in the barn must be moderately high, and the rate of drying must not be too rapid during the first stages of the process.

The disease known as pole-sweat, which is merely a decay of the leaf, is due to excessive moisture in the barn after the leaf has been yellowed. This disease can be readily controlled by the combined use of heat and ventilation.

The application of artificial heat under proper conditions does not injure the quality of cigar tobacco, but on the contrary insures better curing, especially as regards the color of wrapper leaf. It has given particularly good results with picked or primed tobacco.

To apply artificial heat effectively and economically requires a reasonably tight barn, and adequate ventilation must be provided to control properly the humidity. The heating system should have sufficient capacity to maintain in the barn a temperature from 15 to 20 degrees above that of the outside air.

Open charcoal fires are used successfully in curing shade-grown tobacco, but charcoal is an expensive fuel, the supply is limited, and properly to care for the large number of fires required is a laborious task. This method of applying heat would be decidedly more expensive in the case of ordinary picked or primed tobacco and when tobacco is cured on the stalk.

A method has been devised for applying artificial heat by means of a system of furnaces and flues in which wood is used as fuel. In this method a furnace and set of flues are required for each "bent" or 16-foot section of the barn. An important feature of the system is a ventilator extending along the peak of the roof. Details regarding the construction and use of this system have been outlined. It has been fully demonstrated by tests conducted on a large scale that this method gives excellent results in curing, especially in the case of tobacco harvested by picking the leaves from the stalk.

Moderate-sized barns with low, flat roofs, which can be completely filled with tobacco in one or two days, are best adapted to the use of artificial heat in curing.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 242.

B. T. GALLOWAY, *Chief of Bureau.*

SEEDS AND PLANTS IMPORTED

DURING THE PERIOD FROM APRIL 1 TO JUNE 30, 1911:

INVENTORY No. 27; Nos. 30462 to 31370.

Issued May 31, 1912.

WASHINGTON:
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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY,
OFFICE OF THE CHIEF,
Washington, D. C., January 20, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 242 of the series of this Bureau the accompanying manuscript, entitled "Seeds and Plants Imported during the Period from April 1 to June 30, 1911: Inventory No. 27; Nos. 30462 to 31370."

This manuscript has been submitted by the Agricultural Explorer in Charge of Foreign Seed and Plant Introduction with a view to publication.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

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B. P. I.—723.

SEEDS AND PLANTS IMPORTED DURING THE PERIOD FROM APRIL 1 TO JUNE 30, 1911: INVENTORY NO. 27; NOS. 30462 TO 31370.

INTRODUCTORY STATEMENT.

It is not generally realized by the public that the area of inhabited country on the globe which is visited by zero temperatures is limited to the Northern Hemisphere and to the tops of mountains. A temperature such as is prevalent on our Great Plains every winter would practically wipe off the vegetation from the continents lying below the equator and would so injure the agriculture even of central Europe that it would require many years in which to recover. The eucalypts are trees which we can not grow north of Florida or California, and yet there are varieties which grow well on the west coast of Scotland.

The limited area which can be explored with any hope of obtaining perennial plants hardy enough to thrive on our Great Plains should give any exploration of such areas special importance.

The present inventory contains descriptions of plant material obtained by Mr. Frank N. Meyer during an exploration trip across the great Tien Shan mountain range, which lies between Chinese and Russian territory, a region with passes 13,000 feet above the sea and possessing a climate approaching that of the upper Mississippi Valley. The winters are long and cold, and the thermometer goes down to −20° F. or more, while the summers are extremely hot, though possibly not so long as those in our Middle West.

Mr. Meyer left Kashgar in Chinese Turkestan on February 10, and on foot or by native cart he traveled across the alkali and sandy deserts for 13 days to Aksu, at the foot of the Tien Shan Range, picking up some desert poplars on the way. Here he changed his desert caravan for a mountain-climbing equipment and with a mounted guard climbed northward over the range by way of Awat, Yengi-Malah, Kailik, and Tanga-Tash over the Muzart Glacier to Ghilan, thence eastward along the Tekes River to a point on the Chong Djighilan River east of the hamlet of Chong Djighilan, and from there worked his way northwestward in the valley of the Ili to Kulja, spending 40 days on the road. The difficulties of travel in any poorly mapped region are great, but they were made even greater by the fact that the region mentioned is the very boundary line between the Russian and the Chinese Empires and that at that time the Kulja, or Ili, district was a subject of international dispute between the two countries.

In the journey through the alkali desert Mr. Meyer secured some promising desert poplars and cuttings of that important drought and alkali resistant tree, the tamarisk (Nos. 30930 to 30933), to which enough attention has not yet been paid by dwellers in desert regions who are looking for cover plants and sand binders. Crossing the Tien Shan Range he reached altitudes of 13,000 feet and traveled through forests of the rare spruce *Picea obovata schrenkiana*, a form which may have a distinct future as a park and avenue tree in the elevated semiarid regions of this country where the Norway spruce fails. On March 16 and 17 Mr. Meyer discovered wild apricot and wild apple trees (Nos. 30946 to 30949 and 30952) standing in 2 feet of hard-frozen snow on the north side of an otherwise barren mountain near Tugai. In the valley of the Chong Djighilan River groves of these wild fruits occur, the slow-growing trees varying in all possible ways. They grow in the company of birches, sea buckthorn, hawthorn, and other northern species, and Mr. Meyer is forced to the conclusion from his study of the wild orchards which he saw there that these wild species will give rise to strains of very much hardier varieties of both these orchard fruits than any we now possess. Our apples and apricots have no doubt come to us from their wild homes through the mild regions of Europe, and this reaching back to the original wild hardy forms can not fail to be of importance to the breeders who are interested in the production of hardier varieties. Owing to the fact that it took two months for the cuttings to reach Washington (though gathered in March they did not reach here until May 17), it proved impossible to save them. Arrangements for their reintroduction are under way.

Some of the other plants which were secured on this trip are an ornamental Euonymus (No. 31276) from the Ili Valley, which is likely to be hardier than *E. radicans*, so much used on the walls of our houses; a valuable collection of the named varieties of winter melons of the Casaba type (Nos. 31335 to 31352) from the sand dunes of Tcharjui; two yellow-flowered alfalfas from an altitude of 4,000 to 7,000 feet (Nos. 30954 and 30955); two wild currants from Idin-Kul (Nos. 30943 and 30944); a collection of hardy willows for park planting in the Northwest (Nos. 30923 to 30929); and a collection of five varieties of apricots, one of them a dark-red sort, from Bis-Karim (Nos. 30628 to 30632).

Mr. C. V. Piper, of the Office of Forage-Crop Investigations, temporarily detailed to the Bureau of Insular Affairs of the War Department for the purpose of making a study of the forage-crop problems of the Philippine Islands, left that detail on July 5 and started on an agricultural exploration for this office. His collections which are recorded here are only such as were made by him previous to leaving the Philippines. They include, among other forage grasses and grains, soft-seeded varieties of the grass known as Job's-tears (*Coix lachryma-jobi ma-yuen*), which Mr. Piper believes are promising as summer grain crops (No. 30715).

Of the plant material sent in by correspondents and through the American consuls the following are worthy of special attention: A strong, fruitful variety of the chayote (No. 30462), other varieties of which vine have been disappointing in our experiments because of their shy-bearing habits; roots of the white ginger from China (Nos. 30483 and 30592) that may demonstrate the possibility of ginger culture in this country; a wild species of Persea (No. 30494) from Panama which the avocado growers of Florida and California may be glad to try as a stock; the arayan from Mazatlan, Mexico (No. 30499), a rich, juicy, tropical fruit that deserves to be improved, as it represents one of a large number of tropical myrtles which have good edible fruits; plants of the Laranja da Terra (No. 30605), a variety or local strain of orange, which is used as a stock for the navel orange in Bahia, Brazil, where this orange is supposed to have originated; a collection of the remarkable soy beans of Manchuria (Nos. 30593 to 30601), the value of which for producing a paint oil and for use in the manufacture of human food has been recently so strongly emphasized; the sweet lime of Palestine (No. 30620) which, according to Mr. Aaron Aaronsohn, is preferred as a stock for the famous seedless Jaffa orange, because the trees require less irrigation and fruit earlier than the bitter orange; the Shibu kaki of Japan (No. 30678), a variety of persimmon which is not edible, but from which the remarkable waterproofing called "Kaki-no-shibu," a fermented product, is made; a new pine (No. 30688), which grows to a height of 200 feet and has cones 12 inches long, discovered by Mr. George Forrest in the Lichiang mountain range of western Yunnan; a lemon variety (No. 30737) from an altitude of 4,000 feet in the Himalayas, which is not injured by the snowfalls and rather severe frosts of that region; a shrubby fruit plant of the annona family (No. 30835) from British West Africa that is burned to the ground each year and may adapt itself to the annual freezes of Texas and northern Florida; *Sorbus torminalis* (No. 30892) from southern Russia, which is suggested by Mr. Theo. Kryshtofovich as a stock for the pear on account of its remarkable drought resistance; seeds from good fiber-bearing varieties of the New Zealand flax (Nos. 30831 and 30832) from Auckland; two species of passifloras from the Caucasus (Nos. 30902 and 30903) and one from Uruguay (No. 31207) for the use of any breeder who will undertake the hybridization of the maypop; the remarkable akala berry from Hawaii (*Rubus macraei*, No. 30907), with fruits 2 inches in diameter, of a deep-red color, and with an agreeable, slightly bitter taste, also imported for breeding purposes; bud sticks of seven of the standard commercial varieties of the Spanish carob (Nos. 30914 to 30920), a fodder tree of decided importance for the cheap lands of California; a remarkable collection of 29 varieties of Medicago (Nos. 30992 to 31024) and 14 of clover (Nos. 31043 to 31057) from St. Petersburg; 77 varieties of rice from the Philippines (Nos. 31116 to 31192); a tropical leguminous plant, Sphenostylis (No. 31194), which forms edible tubers with a taste similar to that of the potato; the Palma de Chile (*Jubaea chilensis*, No. 31097), a drought-resistant palm which is rapidly being exterminated by the manufacturers of Miel de Palma, a much-sought-for sirup which is made from its sap; and two unusual forms of the potato (Nos. 31230 and 31231) from 10,000 feet altitude in the interior of Peru, where they are cultivated by the Hill Indians of the Perene.

As heretofore, the inventory has been compiled by Miss Mary A. Austin and the botanical identifications and the notes on geographic distribution have been prepared by Mr. H. C. Skeels under the general direction of Mr. Frederick V. Coville, of the Office of Taxonomic and Range Investigations. With regard to these geographic notes it should be pointed out that they give only the distribution of the species as recorded in the available literature and no pretense is made to an exhaustive investigation of the distribution of any of the species.

DAVID FAIRCHILD,
Agricultural Explorer in Charge.

OFFICE OF FOREIGN SEED AND PLANT INTRODUCTION,
Washington, D. C., December 20, 1911.

INVENTORY.

30462. CHAYOTA EDULIS Jacq. **Chayote.**

From Algiers, Algeria. Presented by Dr. L. Trabut. Received April 1, 1911.

"*Chayotte verte grosse* (large green chayote). This variety is very strong and very fruitful." (*Trabut.*)

These are specimens of the strain annually exported from Algiers in very large quantities to the larger cities of Europe.

30463. PRUNUS ARMENIACA L. **Apricot.**

From Tai Ming Fu, North China. Presented by Mr. Horace W. Houlding. Received at the Plant Introduction Garden, Chico, Cal., March 27, 1911. Numbered April 1, 1911.

"This apricot is called the *Mammoth.*" (*Houlding.*)

30464 to 30466. SACCHARUM OFFICINARUM L. **Sugar cane.**

From Tainan, Formosa, Japan. Presented by Mr. Takiya Kawakami, Bureau of Productive Industry, Government of Formosa, Taihoku, Formosa, Japan. Received April 1, 1911.

Plants of the following:

30464. *Chiku-cha.*

30465. *An-cha.*

30466. *Ra-cha.*

See No. 28193 for purpose for which introduced.

30467 and 30468. VITIS VINIFERA L. **Grape.**

From Tiflis, Trans-Caucasia, Russia. Presented by Mr. A. Rolloff, director, Tiflis Botanical Garden. Received April 1, 1911.

Cuttings of the following:

30467. *Tavris.*

30468. *Ksil-isjum.*

"The fruits of these table varieties bear transportation very well." (*Rolloff.*)

30469 to 30472. CUCUMIS MELO L. **Muskmelon.**

From Diarbekr, Kurdistan, Asiatic Turkey. Presented by Mr. W. W. Masterson, American consul, Kharput, Asiatic Turkey. Received April 1, 1911.

Seeds of the following winter varieties; notes by Mr. Masterson:

30469. "Elongated; coarse network; greenish white interior."

30470. "Large size; ball shaped; fine network; greenish white interior."

30471. "Ball shaped, but sectioned; yellow exterior; white interior."

30472. "Ball shaped; fine network; greenish white interior; medium size."

30473. PHOENIX DACTYLIFERA L. **Date.**

From Fez, Morocco. Presented by Mr. J. Thomson, Hotel Reina Cristina, Algeciras, Spain. Received April 4, 1911.

Tafilelt. See No. 18630 for description.

Seeds.

30474. NICOTIANA TABACUM L. **Tobacco.**

From Orizaba, Vera Cruz, Mexico. Presented by Mr. George Young, secretary, The Cananea Consolidated Copper Co., Cananea, Sonora, Mexico, who procured it from Gustavo Mayer y Cia., of Orizaba. Received April 3, 1911.

San Cristobal. "This seed is from one of the best plantations of the Valle Nacional and produces about the highest grade of Mexican tobacco. It was gathered from plants specially cultivated for seed. The nursery was made in the latter part of August and the plants were transplanted on the 1st of October. They suffered from no disease or insects. The original seed came from Havana about 20 years ago, but this is the first time that seed has been gathered from special plants." (*Gustavo Mayer y Cia.*)

30475 to 30477.

From Piracicaba, Brazil. Presented by Prof. Clinton D. Smith, Escola Agricola Pratica Luiz de Queiro. Received April 5, 1911.

Seeds of the following; quoted notes by Prof. Smith:

30475. CAESALPINIA PECTINATA Cav. **"Tara-tara."**

Distribution.—In the vicinity of Popayan, Colombia, and in Peru and Brazil.

30476 and 30477. PSIDIUM GUAJAVA L. **Guava.**

30476. "From selected fruits of white-fleshed guavas."

30477. "Seed from red-fleshed guavas."

30480. SPONDIAS LUTEA L. **Hog plum.**

From Rio de Janeiro, Brazil. Presented by Mr. Antonio Augusto Pereira da Fonseca. Received April 5, 1911.

"*Caja mirim.* Fruit edible." (*Fonseca.*)

Distribution.—From the provinces of Yucatan and Tabasco in southern Mexico southeastward through Central America to Colombia and northern South America and in the West Indies.

30481. TRIFOLIUM SUAVEOLENS Willd. **Shaftal.**

From Tiflis, Caucasus, Russia. Presented by Dr. Richard Schmidt, assistant director, Caucasus Museum and Public Library. Received March 30, 1911.

"This plant grows on comparatively xerophilous places, which receive water almost only in the spring from rainfalls and floods. It is very fragrant, so that one can notice the blooming clover meadows a kilometer away by the sweet odor. The soil on which it grows is a light, warm, penetrable, yellow loam, a sort of loess. It contains lime, clay, and silicic acid." (*Schmidt.*)

30482. AMYGDALUS sp. **Chinese flat peach.**

From about 50 miles southwest of Tsinan, Shantung, China. Presented by Mr. T. B. Neal, Union Medical College, Tsinan. Received April 8, 1911.

Feicheng. "This is a large, luscious cling, very much esteemed by the Chinese. I had to depend upon the word of the man I sent down into the country to buy these cuttings to guarantee their genuineness, so I send them with all reserve." (*Neal.*)

See Nos. 21989 and 29991 for previous introductions.

30483. ZINZIBER OFFICINALE Rosc. **White ginger.**

From Weihsien, China. Presented by Mr. A. H. Mateer. Received April 8, 1911.

"This is planted in ground that has been spaded to the depth of nearly a foot, but which is firm and solid underneath. This is to keep it from sending out rootlets deep

30483—Continued.

down and lead the strength of the plant to producing tubers, like the effect on a pot-bound plant of making it do something besides make rootlets. The ground should not be too dry, and this kind of soil will be all right without watering, except at first. In our region (latitude of Kentucky) it is planted in trenches dug as described, in April, in black and sandy soil (that is what the man said, though it seems to me like a contradiction), and the ground is not enriched. It is dug in the autumn. The price now (March 4) is about 5 cents a pound, but two months ago it was less than 3 cents, and in a month or two it will be twice as much." (*Mateer.*)

30486. ANNONA sp. **Annona.**

From Para, Brazil. Presented by Mr. Walter Fischer, acting director, Campo de Cultura Experimental Paraense. Received April 7, 1911.

"About three years ago Dr. J. Huber brought the original seed of this from the River Purus; a year ago I planted several of the young trees on the station grounds and the seeds are from fruits from these trees.

"The fruit is almost spherical and only slightly heart shaped; it is smooth and of a greenish orange color; weight about 6 ounces; meat of a beautiful orange and in fair quantity; taste, like that of all the annonas, difficult to describe, but with a suggestion of rosin, and not unlike some apples I have eaten; probably capable of improvement, and fruits may become larger on older trees. The tree in general aspect as well as in its bark and foliage strongly resembles the persimmon." (*Fischer.*)

30487. PASSIFLORA LIGULARIS Juss. **Passion fruit.**

From Orizaba, Vera Cruz, Mexico. Presented by Mr. William W. Canada, American consul, Vera Cruz. Received April 10, 1911.

30488. ZIZIPHUS JUJUBA Miller. **Jujube.**

From Chingchowfu, via Kiaochow, China. Presented by Mr. W. M. Hayes, Gotch-Robinson Union Theological College. Received April 10, 1911.

"Cuttings of the largest variety of Chinese dates that I could hear of. The Chinese claim that they are not easy to graft successfully, so they will have to be given the best possible chance." (*Hayes.*)

30491. SPONDIAS PINNATA (L.) Kurz.

From Sibpur, Calcutta, India. Presented by Maj. A. T. Gage, superintendent, Royal Botanic Garden. Received April 11, 1911.

Distribution.—A small tree occurring both wild and cultivated throughout India from the Indus eastward and southward to Malakka and Ceylon, rising to an elevation of 5,000 feet in the Himalayas; cultivated throughout tropical Asia.

30492 to 30494.

From Panama. Collected by Mr. H. Pittier, Bureau of Plant Industry. Received April 13, 1911.

30492. RHEEDIA EDULIS (Seem.) Planch. and Triana. **Sastra.**

See No. 27485 for description.

Seeds.

30493. ARRACACIA XANTHORRHIZA Bancr. **Arracacha**

From Chiriqui.

Tubers.

30494. PERSEA sp. **Avocado.**

"A wild species of avocado which may be a good stock for grafting the finer varieties." (*Pittier.*)

Seeds.

30495. SPONDIAS CYTHEREA Sonnerat. **We fruit.**

This plant has generally been known under the name *Spondias dulcis* Forster, which was published in 1786 (De Plantis Esculentis, p. 33). Mr. P. J. Wester has called attention to the publication in 1782 of *Spondias cytherea* Sonnerat (Voyage aux Indes Orientales et a la Chine, vol. 2, p. 222, pl. 123), and as this is undoubtedly the same species as the one described by Forster, the earlier name should be used.

From Brisbane, Queensland, Australia. Presented by Mr. J. F. Bailey, director, Department of Agriculture and Stock. Received April 11, 1911.

See No. 26470 for description.

30496. MAIHUENIA POEPPIGII (Otto) Philippi.

From Chile. Received through Mr. José D. Husbands, Limavida, via Molina, Chile. Received April 13, 1911.

"*Opuntia maihuen* (Herba del Gunaco). A valuable plant for industry and ornament. Grows in dry, worthless, sandy waste, where nothing else will grow. The skinned plant and fruit are eaten as a refreshment. The plant contains an extra large quantity of gum, which I believe to be of industrial use and value. It completely covers the loose sand for about a meter in diameter. Collected from the drifting sands near the Volcano Antuco." (*Husbands.*)

30497. DIOSPYROS TESSELLARIA Poir.

From Port Louis, Mauritius. Presented by Mr. Gabriel Regnard. Received April 10, 1911.

See No. 30139 for previous introduction.

30498. WARNERIA AUGUSTA Stickman. **Cape jasmine.**

(Herbarium Amboinense, in Linnæus's Amoenitates Academicae, vol. 4, 1759, pp. 136, 138.)

The Cape jasmine has heretofore been listed in the Inventories as *Gardenia jasminoides* Ellis (Philosophical Transactions, vol. 51, 1761, p. 935. pl. 23). The following quotation from Ellis's article throws considerable light on this name:

"In July, 1758, I procured a specimen from Mr. Warner, for my friend, Dr. Linnæus's opinion. At the same time I wrote to the professor [Linnæus] that if he found it to be a new genus, agreeable to the description I had sent him, that he would please to call it Warneria after its worthy possessor [Richard Warner, of Woodford, in the county of Essex, England, the author of Plantae Woodfordienses, 1771]. * * * But Mr. Warner, refusing to have it so called and choosing that it should still remain a jasmine, as it is commonly called, I have thought of no man more worthy as a botanist than our friend Dr. Garden; accordingly, the professor has agreed to adopt this new genus by the name of Gardenia."

However, the generic name Warneria, suggested by Ellis, was actually published by Stickman two years before the publication of Gardenia. It was based on the plant described and figured by Burmann (Rumph's Herbarium Amboinense, vol. 7, 1755, p. 26, pl. 14) with the specific name *augusta* (spelled *Varneria augusta* on p. 136, and *Warneria angusta* on p. 138). This description and plate are generally accepted as applying to the Cape jasmine, and were cited by Linnæus in the first place in which he described the plant, under the name *Gardenia florida* (Species Plantarum, ed. 2, 1762, p. 305). Under present rules of botanical nomenclature this use of the binomial *Warneria augusta* and the citation of a previously published description

30498—Continued.

constitutes botanical publication, and it is therefore necessary to use this name for the Cape jasmine.

From Kuling, China. Presented by Mrs. John Berkin. Received March 1, 1911.

"Seeds of the favorite spring flower of the Chinese. In drying, the seeds stain the paper a bright yellow, which is indelible, as I found on my fingers. The Chinese use it in producing their yellow dyes. The bush is graceful and evergreen; the leaves are oblong; the flowers resemble a double white camellia, but with most exquisite perfume. It is a profuse bloomer, the flowers maturing before the leaf buds, being one of the earliest spring flowers.

"The seed pods are very much like those of the rose, but a bright orange yellow in color, and are quite ornamental on the bush among the leaves. Chinese name is Romanized *Chi-tse* flower." (*Berkin.*)

30499. MYRTUS ARAYAN H. B. K. **Arayan, or arrellano.**

From Mazatlan, Mexico. Collected by Mr. J. M. Goulding. Presented by Mr. F. W. Popenoe, Altadena, Cal. Received April 10, 1911.

"This tree grows to be 20 to 35 feet high, the trunk sometimes 15 inches in diameter, with smooth gray bark and erect branches. It seems to be cultivated somewhat extensively in Mexico. Fruit is greenish yellow, with a large irregular disk at the top and a smooth nutlet in the center; very juicy and said to have a rich, spicy, subacid flavor. One of the popular soft drinks of the country, said to be very refreshing, is made from it." (*Rose, J. N. Notes on Useful Plants of Mexico. Contributions from U. S. National Herbarium, vol. 5, no. 4.*)

Distribution.—From Panama southward to Peru.

30500 to 30503.

From central Asia. Presented by Dr. Isaac Bayley Balfour, director, Royal Botanic Garden, Edinburgh, Scotland. Received April 14, 1911.

Seeds of the following:

30500. HORDEUM VULGARE L. **Hull-less barley.**

Variety.

30501 and 30502. APOCYNUM HENDERSONI Hook.

"This yields the fiber from which the people largely make rope." (*Balfour.*)

One or two of the central Asian species of this genus give fiber especially suited for use in paper making, and this may also prove of value for this purpose.

30501. Brown fiber. **30502.** White fiber.

30503. CANNABIS SATIVA L. **Hemp.**

Female.

30504. MEDICAGO SATIVA L. **Alfalfa.**

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, agrostologist and botanist, Transvaal Department of Agriculture. Received April 17, 1911.

"Chinese lucern. This variety is described as growing equally well on hillsides and in valleys, even at high altitudes, where it is said to attain a height of 4 or 5 feet. It is also said to thrive in very salty, marshy land. I am unable to vouch for the correctness of these statements, but the plant seems to be worth trial." (*Davy.*)

30505 and 30506. Hordeum spp. **Barley.**

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, agrostologist and botanist, Transvaal Department of Agriculture. Received April 17, 1911.

Seeds of the following:

30505. Hordeum sp.

Nepaul.

30506. Hordeum vulgare trifurcatum (Schlecht.) Beaven.

30508. Larix leptolepis (Sieb. and Zucc.) Gord. **Japanese larch.**

From Copenhagen, Denmark. Presented by Mr. S. T. Dana, Acting Chief of Silvics, Forest Service, U. S. Department of Agriculture, who procured it from Mr. Johannes Rafn. Received April 17, 1911.

See No. 6672 for previous introduction.

Distribution.—Slopes of the mountains in northern and central Japan extending from Hokushu southward to the region around Yokohama.

30509. Magnolia campbellii Hook. f. and Thoms. **Magnolia.**

From Sibpur, Calcutta, India. Purchased from Maj. A. T. Gage, superintendent, Royal Botanic Garden. Received April 17, 1911.

See No. 28660 for previous introduction.

Plants.

30510. Musa basjoo Sieb. and Zucc. **Plantain.**

From Chiddingfold, Surrey, England. Purchased from V. N. Gauntlett & Co. (Ltd.). Received April 17, 1911.

"This is not hardy at Kew, but in the southwest of England (Cornwall) it can be grown in the open air, though even there it runs risks." (*Dr. David Prain, director, Royal Botanic Gardens, Kew, England.*)

Distribution.—In the Nansei Archipelago and also cultivated in the southern part of Japan.

30511. Lycoris aurea (L'Herit.) Herbert.

From Yachowfu, Szechwan, China. Presented by Mr. C. A. Salquist at the request of Mr. H. J. Openshaw. Received April 22, 1911.

"Bulbs of a yellow lily. I have not seen this particular kind of a lily in America, but it may be quite common." (*Salquist.*)

Distribution.—A bulbous plant found in the provinces of Kiangsu and Hupeh in China, an[illegible]us [illegible]ated in Japan.

, the

30512. [illegible]um verum Hemsl. **White rubber.**

Caucho blanco.

From the plantation "La Tigra," Cuesta de Tocota, on the road from Cali to Buenaventura, Colombia. Procured by Mr. Henry J. Eder, former American consular agent at Cali, Colombia; forwarded through Mr. Charles H. Small, American vice and deputy consul general, Bogota, Colombia. Received April 19, 1911.

See No. 24640 for description.

Seeds.

30513. NICOTIANA TABACUM L. **Tobacco.**

From Manicaragua, Santa Clara, Cuba. Presented by Mr. Francisco A. Montero, Santa Clara, Santa Clara Province, Cuba. Received April 18, 1911.

"Considered by experts of this country as the best variety of tobacco in the island of Cuba." (*Montero.*)

30514. CASTILLA PANAMENSIS Cook. **Central American rubber.**

From Panama. Collected by Mr. H. Pittier, Bureau of Plant Industry. Received April 20, 1911.

One of the six rubber-producing trees of this genus native to Panama, where it was collected by the Smithsonian Institution Biological Survey of the Canal Zone.

Seeds.

30515. PASSIFLORA EDULIS Sims. **Passion fruit.**

From Raratonga, Cook Islands. Presented by Mr. North Winship, American consul, Tahiti, Society Islands. Received April 20, 1911.

"These fruits are not grown in Tahiti, but are imported as a table fruit." (*Winship.*)

30516 to 30521.

From Buitenzorg, Java. Presented by the Director of Agriculture. Received April 21, 1911.

Seeds of the following:

30516 and **30517.** TALAUMA MUTABILIS Blume.

30516. See No. 28794 for previous introduction.

30517. Variety *longifolia.*

30518 to **30521.** DIOSPYROS spp.

These species were introduced for the work of testing all the procurable species of this genus as stocks for the better varieties and for breeding purposes.

30518. DIOSPYROS DISCOLOR Willd.

30519. DIOSPYROS sp.

30520. DIOSPYROS CAULIFLORA Blume.

Distribution.—At an elevation of 500 feet on the calcareous mountains in the province of Bantam, Java.

30521. DIOSPYROS MACROPHYLLA Blume.

Distribution.—On the slopes of the mountains in the island of Java.

30522 to 30584.

From Tiflis, Caucasus, Russia. Presented by Mr. A. Rolloff, director, Botanic Garden. Received April 18, 1911.

Seeds of the following:

30522. PAEONIA CORALLINA Retz. **Peony.**

Distribution.—Central and southern Europe, and eastward to Armenia and northern Persia.

30523. PAEONIA MLOKOSEWITSCHI Lomakin. **Peony.**

See No. 27674 for previous introduction.

30524. CASTALIA ALBA (L.) Greene. **Water lily.**

Distribution.—Lakes and slow streams throughout Europe, and in northern and central Asia.

30522 to 30584—Continued.

30525. PAPAVER ORIENTALE L. **Poppy.**

Distribution.—Throughout the Caucasus region and northern Persia; generally cultivated.

30526. CRAMBE ORIENTALIS L.

Distribution.—Asia Minor, Kurdistan, and eastward through northern Syria to Persia.

30527. TAMARIX HOHENACKERI Bunge. **Tamarisk.**

Distribution.—Saline regions in the vicinity of Tiflis in the Caucasus region.

30528. TILIA FLAVA Wolny. **Linden.**

Distribution.—On the slopes of the Balkan Mountains in Bulgaria and Bosnia, and in Asia Minor.

30529. ERODIUM CICONIUM (Juslen.) Willd.

Distribution.—The countries bordering on the Mediterranean from Spain and Italy eastward to Syria.

30530. ERODIUM OXYRHINCHUM Bieb.

Distribution.—Sandy hillsides in the Caucasus region and eastward through northern Persia to Turkestan.

30531. ACER TRAUTVETTERI Medw. **Maple.**

Distribution.—The Caucasus region of southeastern Russia and northern Persia.

30532. ACER INSIGNE Boiss. and Buhse. **Maple.**

Distribution.—On the slopes of the mountains in the provinces of northern Persia bordering on the Caspian Sea.

30533. ACER LAETUM Meyer. **Maple.**

Distribution.—In woods in Armenia and the northern part of Persia.

30534. STAPHYLEA PINNATA L. **Bladder nut.**

Distribution.—Southern Europe and western Asia extending from Germany and Italy eastward to the Caucasus region and to Syria.

30535. EUONYMUS EUROPAEUS L. **Spindle tree.**

See No. 2660 for previous introduction.

Distribution.—Throughout Europe and eastward to the region of the Ural Mountains in Siberia.

30536. RHAMNUS CATHARTICUS L. **Purging buckthorn.**

See No. 30246 for previous introduction.

30537. RHAMNUS FRANGULA L. **Alder buckthorn.**

See No. 30248 for previous introduction.

30538. RHAMNUS IMERETINUS Booth. **Buckthorn.**

Distribution.—The province of Kars in the Trans-Caucasian region of southeastern Russia.

30539. TRIFOLIUM ARVENSE L. **Rabbit-foot clover.**

See No. 9751 for previous introduction.

30540. TRIFOLIUM SPUMOSUM L. **Clover.**

See No. 30102 for previous introduction.

30541. TRIFOLIUM TUMENS Stevens. **Clover.**

Distribution.—In low fields and on mountain slopes in the Caucasus region.

30522 to 30584—Continued.

30542. Trifolium ambiguum Bieb. **Clover.**

Distribution.—High fields and lower alpine slopes of the mountains in the Caucasus region, and in Armenia.

30543 and 30544. Trifolium filiforme L. **Suckling clover.**

See No. 20662 for previous introduction.

30545. Melilotus neapolitana Tenore.

Distribution.—The countries bordering on the Mediterranean from Spain and southern France through Italy, the Balkan Peninsula, and Asia Minor to Persia, and in northern Africa.

30546. Caragana grandiflora DC. **Siberian pea tree.**

Distribution.—On dry hillsides in the Trans-Caucasian region of Russia, and in Armenia, and the region around the Caspian Sea.

30547. Astragalus cruciatus Link.

Distribution.—In dry and rocky fields in Asia Minor and Syria.

30548. Astragalus hamosus L.

See No. 30108 for previous introduction.

30549. Astragalus viciaefolius DC.

Distribution.—The Caucasus region of Russia and in Asia Minor.

30550. Astragalus densifolius Lam.

Distribution.—On the subalpine slopes of the mountains in Armenia.

30551. Astragalus mollis Bieb.

Distribution.—Arid places in the Caucasus region and in Armenia and western Persia.

30552. Astragalus galegiformis L.

See No. 4140 for previous introduction.

Distribution.—Slopes of the mountains in the Trans-Caucasian region and in Armenia.

30553. Astragalus schahrudensis Bunge.

Distribution.—The provinces of northern and central Persia; especially frequent in the vicinity of Teheran.

30554. Astragalus falcatus Lam.

See Nos. 20708 and 20727 for previous introductions.

Distribution.—The Caucasus region of southern Russia, the region of the Ural Mountains of Siberia, and in Armenia.

30555. Astragalus cephalotes Pallas.

Distribution.—The Trans-Caucasian region of Russia and in northern Persia.

30556. Astragalus sanguinolentus Bieb.

Distribution.—Rocky slopes of the eastern Caucasus Mountains in northern Persia.

30557. Astragalus brachycarpus Bieb.

Distribution.—On the slopes of the mountains in the Trans-Caucasian region of southeastern Russia and northern Armenia.

30558. Vicia tenuifolia Roth.

See No. 24465 for previous introduction.

30559. Vicia ervilia (L.) Willd. **Bitter vetch.**

30522 to 30584—Continued.

30560. VICIA HIRSUTA (L.) S. F. Gray.

See Nos. 9237 and 16460 for previous introductions.

Distribution.—Europe and southern Asia, extending from France and Germany eastward to Persia and northern India, and in Abyssinia.

30561. LATHYRUS CICERA L.

Distribution.—Waste places along cultivated fields in central and southern Europe, western Asia, and northern Africa.

30562. GLEDITSIA CASPICA Desf.

See Nos. 27335, 27516, and 27517 for previous introductions.

30563. PRUNUS MICROCARPA Meyer. **Cherry.**

See Nos. 27303, 27337, and 28946 for previous introductions.

30564. PRUNUS PROSTRATA Labill. **Bush cherry.**

See No. 28945 for previous introduction.

30565. LAUROCERASUS OFFICINALIS Roem. **Cherry laurel.**

30566. PYRUS NIVALIS ELAEAGRIFOLIA (Pall.) Schneider. **Wild pear.**

See Nos. 27134 and 27670 for previous introductions.

30567. CRATAEGUS MONOGYNA Jacq. **Hawthorn.**

Distribution.—Throughout Europe and northern Africa and eastward to northern India.

30568. ROSA GALLICA L. **Rose.**

See No. 28237 for previous introduction.

30569. SPIRAEA HYPERICIFOLIA L.

Distribution.—From the Caucasus region and Persia eastward to Mongolia and the region of Lake Baikal.

30570. CORNUS AUSTRALIS Meyer.

Distribution.—The provinces of eastern Turkey, southern Russia, Asia Minor, and northern Persia bordering on the Black and Caspian seas.

30571. LONICERA IBERICA Bieb.

Distribution.—On rocky mountain slopes of the Caucasus region of southeastern Russia and in northern Persia.

30572. LALLEMANTIA IBERICA (Bieb.) Fisch. and Meyer.

See No. 29932 for previous introduction.

30573. DAPHNE CAUCASICA Pallas.

Distribution.—In fields along streams in the Caucasus region and in northern Persia.

30574. ELAEAGNUS ANGUSTIFOLIA L. **Oleaster.**

30575. CELTIS CAUCASICA Willd.

Distribution.—On mountain slopes in Armenia and in northern Persia.

30576. FAGUS ORIENTALIS Lipsky. **Caucasian beech.**

See No. 27662 for previous introduction.

30577. POPULUS TREMULA L. **Aspen.**

See Nos. 29098 and 29357 for previous introductions.

30522 to 30584—Continued.

30578. Iris musulmanica Fomin. (?) **Iris.**

30579. Iris iberica Hoffm. **Iris.**

Distribution.—In the Caucasus region, and in Armenia, and northern Persia, reaching an elevation of 7,000 feet.

30580. Iris acutiloba Meyer. **Iris.**

Distribution.—On dry hillsides in the province of Baku, in the Caucasus region of southeastern Russia and southward to Teheran, Persia.

30581. Iris acutiloba Meyer. **Iris.**

Variety *bimaculata.*

30582. Iris pumila L. **Iris.**

Distribution.—Southern Europe, extending from Austria and Dalmatia eastward to the Caucasus region, and in Siberia.

30583. Iris flavescens Delile. **Iris.**

Distribution.—The Caucasus region of Russia and in Armenia.

30584. Iris pallida Lam. **Iris.**

See No. 28457 for previous introduction.

30585 to 30591.

From the Royal Botanic Garden, Rome, Italy. Presented by Mr. Oglesby Paul, landscape gardener, Horticultural Hall, Fairmount Park, Philadelphia, Pa. Received April 11, 1911.

Seeds of the following:

30585. Araujia sericifera Brot.

Distribution.—A climbing, shrubby vine with small racemes of purple flowers found in Peru and in southern Brazil.

30586. Carica quercifolia (St. Hil.) Benth. and Hook.

See No. 3534 for description.

Distribution.—The southeastern part of Brazil, and in Paraguay, Uruguay, and Argentina.

30587. Ephedra fragilis Desf.

Distribution.—A shrub found in the countries at the western end of the Mediterranean, extending from southeastern Spain and Sicily to the Canary and Madeira Islands, Morocco, and Algeria.

30588. Ephedra altissima Desf.

Distribution.—A shrub found in fields in Morocco and Algeria.

30589. Mallotus japonicus (Thunb.) Muell. Arg.

Distribution.—A small tree occurring in the provinces of Hupeh, Szechwan, and Kwangtung in China, and in Formosa, the Nansei Archipelago, and in Japan.

30590. Peucedanum verticillare (L.) Mert. and Koch.

Distribution.—Southern Europe, extending from France and Spain eastward through Germany and Italy to Austria-Hungary.

30591. Peucedanum oreoselinum (L.) Moench.

Distribution.—Central and southern Europe, extending from Denmark, Germany, and Spain eastward to the Caucasus region of Russia.

30592. Zinziber officinale Rosc. White ginger.

From Tsinan, Shantung, North China. Presented by Mr. J. S. Whitewright, Tsinan Institute. Received April 21, 1911.

"These specimens are, I believe, of somewhat better quality than those formerly sent (No. 29355)." (*Whitewright.*)

30593 to 30601. Glycine hispida (Moench) Maxim. Soy bean.

From Manchuria. Procured through Mr. Edward C. Parker, Agricultural Experiment Station, Mukden, Manchuria. Received April 19, 1911.

Seeds of the following; quoted notes by Mr. Parker:

30593. "Yellow. Chinese name *Huang tou.* Sample collected at Ninguta, in Kirin Province, 45° north latitude. Ninguta is a Chinese town about 10 miles south of the Trans-Siberian Railway and halfway between Harbin and Vladivostok. The Ninguta beans are famous as seed beans, large quantities being distributed among the Chinese in Kirin Province for seed purposes. The date of maturity for this variety is the last week in September, the crop having occupied the land about 130 days. This variety is known to have been grown in the Ninguta district for 40 years, or since the time the country was opened for settlement. Chinese state that the variety is prized for its thin skin, heavy weight per bushel, and its high oil content."

30594. "Green. Chinese name *Ching tou.* Sample collected at Ninguta (see No. 30593). No information is available concerning time of maturity or special qualities of this variety. It has been grown at Ninguta for about 40 years."

30595. "Big, round, green. Chinese name *Tah ching yuan tou.* Sample collected at Antung, in southeast Shengking Province, 40° north latitude. Antung is west of the Yalu River, which divides Chosen (Korea) and Manchuria. No information is available concerning the time of maturity, special qualities, or length of time this variety has been grown in the Antung region. From my own observations, however, I will say that the green soy beans of the Antung region require more time to mature than the small, yellow soy beans of the north. Antung has been settled by Shantung Province people for about 75 years and the variety is doubtless somewhere near the same age. The first recorded exports of soy beans from Manchuria took place from a port in this region (Takushan) about the year 1830."

30596. "Small, round, green. Chinese name *Hsiao ching yuan tou.* Sample collected at Antung (see No. 30595)."

30597. "Big, iron corner, green. Chinese name *Tah tie chiao ching tou.* Sample collected at Antung (see No. 30595)."

30598. "Small, iron corner, green. Chinese name *Hsiao tie chiao ching tou.* Sample collected at Antung (see No. 30595)."

30599. "Compact, round. Chinese name *Chin yuan tou.* Sample collected near Ninguta. Probably the same variety as the 'yellow soy bean' (No. 30593). No description can be furnished other than that given under that number."

30600. "Compact, round. Chinese name *Chin yuan tou.* Sample collected at Shuangchengfu in Kirin Province, 45° north latitude. Shuangchengfu is a Chinese town about 40 miles south of Harbin on the southern division of the Russian railway. One of the most extensive and fertile soil areas in Manchuria is tributary to Shuangchengfu. This variety is undoubtedly the

30593 to 30601—Continued.

30600—Continued.

same common stock as Nos. 30593 and 30599. It matures in about 130 to 140 days and is prized (according to Chinese report) for its thin skin, heavy weight per bushel, and high oil content. It has been grown in this district for about 40 years."

30601. "Compact, round. Chinese name *Chin yuan tou.* Sample collected near Petuna, southwest of Harbin, at the confluence of the Nonni and the Sungari rivers, about 45° north latitude. Soy beans have not been grown more than 15 years in this district because the land was held until recently as an imperial preserve. The variety is doubtless the same common stock as Nos. 30593 and 30599."

30602 to 30604. TRITICUM AESTIVUM L. **Wheat.**

From San Luis Potosi, Mexico. Presented by Mr. Wilbert L. Bonney, American consul. Received April 22, 1911.

Seeds of the following:

30602. Red.

30603. White.

30604. Mixed.

"While San Luis Potosi is not a wheat-growing district, yet there is a certain amount of land to the south and west of the capital where wheat is raised, probably yielding about 200,000 bushels within the State. This wheat land extends southward and westward into Guanajuato and Jalisco. The varieties of wheat raised are red, white, and mixed. Medium-soft red wheat is said to give the best results, and the grade produced improves toward the south of the district mentioned above." (*Bonney.*)

30605. CITRUS sp.

From Bahia, Brazil. Presented by Mr. Southard P. Warner, American consul. Received April 24, 1911.

"Seed of *Laranja da Terra.* This variety of citrus is used extensively at Bahia, the home of the Bahia navel oranges, as a stock on which to graft this remarkable seedless orange which has been so phenomenally successful in America. It is claimed that the Bahia navel when grafted on this stock thrives and bears better than when worked on the other common citrus stock known as the *Laranja tanga.*

"There is some doubt as to whether these are really distinct varieties or simply names given by cultivators to designate seedlings grown on the particular plantation from those grown elsewhere." (*Fairchild.*)

Cuttings of this variety were received and listed under No. 29165.

30606 to 30610. STIPA spp. **Feather grass.**

From Erfurt, Germany. Purchased from Haage & Schmidt. Received April 25, 1911.

Seeds of the following:

30606. STIPA ELEGANTISSIMA Labill.

Distribution.—In the river valleys and along the coast in the provinces of South and West Australia, New South Wales, and Victoria in Australia, and also reported from Tasmania.

30607 and 30608. STIPA GIGANTEA Link.

Distribution.—In sandy places in Portugal and Spain, and in the island of Sicily.

30606 to 30610—Continued.

30609. STIPA PENNATA L.

Distribution.—Europe and western Asia, extending from the British Isles and Spain eastward to western Siberia, Afghanistan, and Armenia.

30610. STIPA SPLENDENS Trin.

Distribution.—The region of Siberia east of Lake Baikal.

30611. PISTACIA ATLANTICA Desf. **Betoom.**

From Maison Carree, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria. Received April 25, 1911.

See No. 9325 for description.

30612 and 30613. SOLANUM NIGRUM L. **Nightshade.**

From France. Presented by Vilmorin-Andrieux & Co., Paris, France. Received April 25, 1911.

Seeds of the following:

30612. "Morelle de l'Ile de France (Mascareigne Brède, nightshade spinach)."

30613. "Morelle noire (nightshade)."

"The former kind, which is cultivated in Mauritius under the name of Brède, does not differ botanically from the common kind (morelle noire), but is more vigorous and larger in all its parts." (*Vilmorin-Andrieux & Co.*)

30614 to 30619. PUNICA GRANATUM L. **Pomegranate.**

Material furnished this office by Mr. T. H. Kearney, Physiologist in Charge, Alkali and Drought Resistant Plant Breeding Investigations, Bureau of Plant Industry. Numbered April 26, 1911.

Plants of the following; notes by Mr. Kearney:

30614. "Green-skinned, sweet variety, from cuttings furnished by Miss Ida Munro, Putnam, Ga."

30615. "Red, sweet, from same source as preceding."

30616. "Subacid, from same source as preceding."

30617. "From Mexico; cuttings furnished by Mr. Alexander Gaw."

30618. "From Mexico; cuttings furnished by Señor Romulo Escobar."

30619. "Cuttings from the hardy bush at the east entrance of the Smithsonian Institution Building, Washington, D. C."

30620 and 30621.

From Palestine. Presented by Mr. Aaron Aaronsohn, director, Jewish Agricultural Experiment Station, Haifa, Palestine. Received April 25, 1911.

Seeds of the following:

30620. CITRUS LIMETTA Risso. **Sweet lime.**

"The Jaffa orange, which is the great commercial orange of Palestine, 800,000 cases being exported annually, is generally grafted on this special sweet lime, which Mr. Aaronsohn writes us is not used either in North Africa or in the United States. As a stock this sweet lime requires less water and produces trees yielding earlier fruit than does the bitter orange." (*Fairchild.*)

30621. ZIZIPHUS JUJUBA Miller. **Jujube.**

"*Anaab*, in Arabic. These seeds came from trees growing in the gardens in the vicinity of Nablus (Shechem) on dry, rocky, and calcareous hills." (*Aaronsohn.*)

30622 and 30623. MEDICAGO SATIVA L. **Alfalfa.**

From Palestine. Presented by Mr. Aaron Aaronsohn, director, Jewish Agricultural Experiment Station, Haifa, Palestine. Received April 25, 1911.

Seeds of the following; notes by Mr. Aaronsohn:

30622. "*Fussa.* The current variety cultivated in and around Damascus."

30623. "*Fussa* (*Menoukhie*). A selected variety of No. 30622."

30624. VACCINIUM VITIS-IDAEA L. **Cowberry.**

From Hamburg, Germany. Presented by Mr. C. Widmaier, inspector, Botanical Gardens and Museum. Received April 26, 1911.

Introduced for purposes of botanical study and breeding work.

Rooted cuttings.

30625 and 30626. COLOCASIA spp. **Dasheen.**

From Hilo, Hawaii. Presented by Mr. F. A. Clowes, superintendent, Hilo and Olaa Substations, Hawaii Agricultural Experiment Station. Received April 25, 1911.

Tubers of the following:

30625. *Palaii.*

30626. *Royal White* or *Lehua keo-keo.*

"Tubers purple fleshed and apparently nonacrid. The sprouts are also purple." (*R. A. Young.*)

See No. 29840 for further remarks.

30627. SPONDIAS PINNATA (L.) Kurz.

From Peradeniya, Ceylon. Presented by Mr. H. F. Macmillan, curator, Royal Botanic Garden. Received April 26, 1911.

30628 to 30671.

Received through Mr. Frank N. Meyer, agricultural explorer, April 24, 1911.

Seeds and cuttings as follows:

30628. PRUNUS ARMENIACA L. **Apricot.**

From Bis-Karim, Chinese Turkestan. "(No. 908, January 20, 1911.) A variety of apricot called *Zeile Anjan.* Fruits medium large, red; early." (*Meyer.*)

30629. PRUNUS ARMENIACA L. **Apricot.**

From Bis-Karim, Chinese Turkestan. "(No. 909, January 20, 1911.) A variety of apricot called *Ak-yarlik.* Fruits of pale color, medium large; ripening early, in June." (*Meyer.*)

30630. PRUNUS ARMENIACA L. **Apricot.**

From Bis-Karim, Chinese Turkestan. "(No. 911, January 20, 1911.) A variety of apricot, called *Kara-Anjan.* Fruits medium large, dark red, fresh, sweet; a late ripener, August." (*Meyer.*)

30631. PRUNUS ARMENIACA L. **Apricot.**

From Bis-Karim, Chinese Turkestan. "(No. 912, January 20, 1911.) A variety of apricot called *Guanauruk.* Fruits large, pale-orange colored. Kernels large and sweet. See also remarks under No. 30311." (*Meyer.*)

30632. PRUNUS ARMENIACA L. **Apricot.**

From Bis-Karim, Chinese Turkestan. "(No. 913, January 20, 1911.) A variety of apricot called *Ak-Tuyan.* Fruits very pale yellow, very large, medium early in ripening. A rare local variety." (*Meyer.*)

30628 to 30671—Continued.

30633. Elaeagnus angustifolia L. **Oleaster.**

From Kashgar, Chinese Turkestan. "(No. 923, January 29, 1911.) This bears large fruits of a pale-orange color. It is a vigorous grower. Seeds sent under No. 30412; see this number for further remarks. Native name *Djigda.*" (*Meyer.*)

30634. Prunus armeniaca L. **Apricot.**

From Kashgar, Chinese Turkestan. "(No. 924, January 31, 1911.) A very early variety of apricot. Fruits smooth, of red color. Kernel sweet." (*Meyer.*)

30635. Malus sp. **Apple.**

From Kashgar, Chinese Turkestan. "(No. 928, February 4, 1911.) An apple called *Kizil alma.* Fruits large, of red color and fresh, sweet taste. Ripens in July. Suitable for hot, dry regions." (*Meyer.*)

30636. Eruca sativa Hill. **Roquette.**

From near Kurvas, Chinese Turkestan. "(No. 1510a, December 4, 1910.) A plant called *Sarich beda,* meaning yellow lucern. Grows as an annual weed in wheat and barley fields at an altitude of about 8,000 feet. Said to be much liked by cattle. To be tested in the cooler regions of the United States." (*Meyer.*)

Distribution.—An annual plant belonging to the mustard family and growing in the countries bordering on the Mediterranean from Spain to Syria and in northern Africa, and extending eastward to Turkestan.

30637. Apocynum venetum L.

From Yarkand, Chinese Turkestan. "(No. 1517a, November 9, 1910.) A fiber plant, growing on moist, saline, sandy places. The natives make ropes and string from the fiber, but it is not considered a very good material. These plants are not cultivated in any way, but grow in a jungle, more or less in the sandy expanses along watercourses. As the rhizomes are capable of running considerable distances, these plants should be tested where there is no chance of their becoming a nuisance. There seems to be some variation in quality and color of the fiber, probably due to soil and to treatment. It is said that this Apocynum fiber is exported from Kulja to Russia and that it forms an ingredient in the Russian bank notes. This variety is called *Ak-chilga,* meaning white fiber, and was collected not far from Yarkand. Obtained through the Hon. George Macartney, British consul, Kashgar." (*Meyer.*)

Distribution.—Southern Europe and Asia, extending from northern Italy through Russia and Dzungaria to China.

30638. Apocynum venetum L.

From Yarkand, Chinese Turkestan. "(No. 1518a, November 9, 1910.) This variety is called *Tokachilga.* It was collected near Merket, to the north of Yarkand, where veritable jungles of it are said to exist. It is supposed to be much taller growing than the preceding number (No. 30637), but is of an inferior quality. It was obtained through the same source." (*Meyer.*)

30639. Citrullus vulgaris L. **Watermelon.**

From Kashgar, Chinese Turkestan. "(No. 1522a, January 28, 1911.) A watermelon of round-oval shape, medium size, light-green rind, dark-red flesh of very sweet taste; seeds black, with curious markings. An early ripener, but not a keeper. To be tested like No. 30396." (*Meyer.*)

30628 to 30671—Continued.

30640. CUCUMIS MELO L. **Muskmelon.**

From Guma, Chinese Turkestan. "(No. 1523a, November 16, 1910.) A large, oval winter melon of excellent keeping and shipping qualities. Rind rough and of yellow color; flesh white, firm, of fresh, sweet taste. Does best in a light, sandy soil.

"All these central Asian melons will do best in those parts of the United States where the summers are very hot and dry and where the soil contains some saline matter." (*Meyer.*)

30641. CUCUMIS MELO L. **Muskmelon.**

From Karawag, Chinese Turkestan. "(No. 1524a, December 10, 1910.) A rare, local variety of melon, called *Tuna.* This melon often grows 1 yard long, while not being any thicker around than a beet root. It will keep until June. The flesh is white, not very juicy, but firm; taste moderately sweet; rind yellowish green; few seeds. Stands shipping remarkably well. Could be served sliced like pineapple at high-class dinners in the middle of winter." (*Meyer.*)

30642. CUCUMIS MELO L. **Muskmelon.**

From Shagra-bazar, Chinese Turkestan. "(No. 1527a, December 23, 1910.) An early melon of medium size and long oval shape. Rind dark green; flesh reddish; not very sweet. A good keeper and shipper. Called *Kara Kutcha.*" (*Meyer.*)

30643. CUCUMIS MELO L. **Muskmelon.**

From Kashgar, Chinese Turkestan. "(No. 1530a, January 28, 1911.) A very early, small melon of green color, flattened shape, slightly ribbed; flesh yellowish green and honeysweet. Called *Kara Kash.*" (*Meyer.*)

30644. PRUNUS ARMENIACA L. **Apricot.**

From Oasis of Sandju, Chinese Turkestan, altitude 6,000 feet. "(No. 1537a, December 4, 1910.) Stones of cultivated apricots, collected here and there. To be sown out in some dry northern locality to obtain hardy types. See remarks made under No. 30355." (*Meyer.*)

30645. PRUNUS ARMENIACA L. **Apricot.**

From Khotan, Chinese Turkestan. "(No. 1538a, November 24, 1910.) A variety of apricot called *Guana* or *Guama uruk.* See remarks made under No. 30311." (*Meyer.*)

30646. PRUNUS ARMENIACA L. **Apricot.**

From Karghalik, Chinese Turkestan. "(No. 1539a, December 12, 1910.) An apricot said to be *Guana uruk.* There are, however, bitter kernels in this lot, and therefore they are mixed, as the *Guana* has large sweet kernels. See remarks made under No. 30311." (*Meyer.*)

30647. AMYGDALUS PERSICA NECTARINA Ait. **Nectarine.**

From Khotan, Chinese Turkestan. "(No. 1540a, November 24, 1910.) A nectarine called *Togatch Moneck.* To be sown in a cold, dry climate to see if hardy types appear among them." (*Meyer.*)

30648. AMYGDALUS PERSICA NECTARINA Ait. **Nectarine.**

From Guma, Chinese Turkestan. "(No. 1541a, November 14, 1910.) A small late variety of nectarine, white in color, of fresh, sweet taste and good keeping qualities. To be sown out like preceding number (No. 30647)." (*Meyer.*)

30628 to 30671—Continued.

30649. Prunus sp. **Plum.**

From Langru, Chinese Turkestan. "(No. 1543a, November 26, 1910.) A plum called *I-nar-low*. Much used as a compote and stewed with meats. Said to aid the digestion of meat." (*Meyer.*)

30650. Berberis sp. **Barberry.**

From Pustan Terek, Chinese Turkestan. "(No. 1549a, December 29, 1910.) A tall-growing barberry; branches armed with long spines and bearing large blue berries. Found between rocks and in stony débris at altitudes of 6,000 to 8,000 feet. Of possible value as an ornamental park and garden shrub in the northern sections of the United States." (*Meyer.*)

30651. Berberis sp. **Barberry.**

From Pustan Terek, Chinese Turkestan. "(No. 1550a, December 29, 1910.) A very spiny, compact-growing barberry, bearing blue berries; found on a stony mountain slope at an altitude of about 7,000 feet. Of possible value as a hedge plant and an ornamental shrub in the northern sections of the United States." (*Meyer.*)

30652. Fraxinus sp. **Ash.**

From Khanaka, Oasis of Sandju, Chinese Turkestan, altitude of 6,000 feet. "(No. 1552a, December 4, 1910.) This number is perhaps the same species of ash as No. 30414, but grew at a much higher elevation. To be tried in the dry, cold sections of the United States. Native name *I-mo-don*." (*Meyer.*)

30653. Colutea sp.

From near Kizil-Kurgan, Russian Turkestan. "(No. 1554a, October 11, 1910.) A spiny shrub growing here and there on dry, sunburned, rocky mountain slopes. Of possible value as an ornamental garden and park shrub in dry and hot sections of the United States." (*Meyer.*)

30654. Caragana sp.

From Pustan Terek, Chinese Turkestan. "(No. 1555a, December 28, 1910.) A Caragana of tall-growing habits, often attaining a height of 6 to 8 feet. Occurs on dry, stony places at altitudes of 6,000 to 8,000 feet. Native name, *Karagan*. Of possible value as an ornamental park and garden shrub in the northern sections of the United States." (*Meyer.*)

30655. Caragana sp.

From Pustan Terek, Chinese Turkestan. "(No. 1556a, December 28, 1910.) A Caragana of very dwarf, compact growth, occurring in stony débris at altitudes ranging from 6,000 to 8,000 feet. Apparently the same as sent under No. 30153. See remarks made under that number. To be tested in the northern sections of the United States. Native name *Karagan*." (*Meyer.*)

30656. Lonicera sp.

From near Irkestan, Russian Turkestan. "(No. 1557a, October 15, 1910.) A shrubby, compact-growing honeysuckle occurring in dry, stony, and windswept places. Cuttings sent under No. 29146, which number see for further remarks." (*Meyer.*)

30657. Rosa sp. **Rose.**

From near Khotan, Chinese Turkestan. "(No. 1558a, November 20, 1910.) A wild rose which, when grown in hedges, attains a height of 10 to 15 feet, but when standing alone only 5 to 6 feet. To judge by the fruits, it seems to be very floriferous. Stands drought and alkali well. Of value, possibly, as an ornamental shrub in large grounds or as a stock in hot, arid regions." (*Meyer.*)

30628 to 30671—Continued.

30658. NITRARIA RETUSA (Forsk.) Aschers.

From near Bis-Wick, Chinese Turkestan. "(No. 1559a.) The desert currant, a species closely allied to that of which seed was sent under No. 29250 from a different locality. See remarks under that number." (*Meyer*.)

Distribution.—The countries along the Mediterranean in northern Africa and eastward through Palestine and Syria to Turkestan.

30659. ASPARAGUS sp. **Asparagus.**

From Ism-Salah, Chinese Turkestan. "(No. 1560a, December 7, 1910.) A wild asparagus found on sandy, saline land. Of slightly twining habit and generally found growing in scattered clumps." (*Meyer*.)

30660. CALLIGONUM sp.

From near Guma, Chinese Turkestan. "(No. 1561a, November 16, 1910.) A small variety existing in absolutely sandy deserts; makes enormous long roots. Grubbed out and used as fuel by the natives. Is of good sand-binding qualities and should be tested for this purpose at some experiment station in a desert." (*Meyer*.)

30661. MELILOTUS ALBA Desr. **Sweet clover.**

From near Susan, Chinese Turkestan. "(No. 1562a, December 7, 1910.) A sweet clover occurring on dry, sandy places. Observed only once. To be tested in a hot, dry region, under irrigation." (*Meyer*.)

30662. ALHAGI PSEUDALHAGI (Bieb.) Desv. **Camel's thorn.**

(*Hedysarum pseudalhagi* Bieberstein, Flora Taurico-Caucasica, vol 2, p. 174, 1808.)

This leguminous manna-producing shrub was first given a distinctive binomial name by Bieberstein in 1808, as *Hedysarum pseudalhagi*. Fischer, in 1812 (Catalogue Jardin Gorenki, p. 72), transferred it to the genus Alhagi but used the name *Alhagi camelorum*, by which the plant has since been known. Desvaux (Journal de Botanique, vol. 1, 1813, p. 120) states that there are two species, *Alhagi mannifera* and *pseudalhagi*, but does not describe them. His evident intention being to publish the binomial *Alhagi pseudalhagi*, he is here given as the authority for the name.

From near San-Kia, Chinese Turkestan. "(No. 1563a, November 17, 1910.) A very prickly, herbaceous, perennial legume, occurring on very dry lands, often in pure sand and shifting sand at that; also found on rather strong alkaline soil. Its uses are as follows: On the places where it abounds in great quantities it is cut and harvested like hay, to be used as a fuel. Most of the bricks in Russian Turkestan have been baked by means of this fuel. It is also a favorite food of the camel, which browses upon the herbage as long as it is not too old; sheep and goats also like it when it is young and the spines have not become too hard. Lastly, as a sand binder it has great value, but only in locations far removed from lands that may become cultivated, for this camel's thorn becomes a very serious pest in cultivated fields and is extremely hard to eradicate, as it throws up suckers from its broken-off roots. The pinkish brown flowers, which appear in enormous masses and give color to whole desert landscapes in the month of June, seem to be rich in honey. This plant should be tested at some experiment station in the desert of the southwestern United States." (*Meyer*.)

30663. IRIS sp. **Iris.**

From near Upal, Chinese Turkestan. "(No. 1564a, December 31, 1910.) An Iris, probably *I. ensata*, found here and there along the fields on rather alkaline soils. The leaves form a very common tying material all through

30628 to 30671—Continued.

30663—Continued.

Chinese Turkestan, being mostly used to tie bunches of vegetables and grapes. Recommended as a tying-material supplier in the vegetable garden and as a lining plant along flower or shrubbery beds in dry, alkaline sections. It is said to flower prettily in early summer with small, pale-blue flowers. Probably a variety of No. 29264." (*Meyer.*)

30664. ELYMUS DAHURICUS Turcz. **Wild rye.**

From Pustan Terek, Chinese Turkestan, altitude of 6,000 to 7,000 feet. "(No. 1565a, December 29, 1910.) A tall perennial rye-grass occurring on dry loess banks along a ravine. Apparently rare. The long strong stems of golden-yellow color could be used perhaps to make straw braid; also to sip cool drinks through. To be tested in the Rocky Mountain regions or farther west." (*Meyer.*)

Distribution.—Dry, stony places in the southern part of Siberia from Turkestan eastward to the region beyond Lake Baikal.

30665. AGROPYRON ACUTUM (DC.) Roem. and Schult.

From Pustan Terek, Chinese Turkestan. "(No. 1566a, December 29, 1910.) A tall grass, occurring intermixed with the preceding one. May possess value as a forage grass in dry mountainous regions." (*Meyer.*)

Distribution.—Considered to be a possible hybrid between *Agropyron repens* and *A. junceum*, growing throughout Europe and eastward to China.

30666. SESLEREA ARGENTEA Savi.

From near Gagri, Caucasus, Russia. "(No. 1567a, February 1, 1911.) Found on mountain slopes between boulders and washed-down earth. May possess value as a fodder grass in mild-winter regions." (*Meyer.*)

Distribution.—Southern Europe and western Asia, extending from Spain through Italy, the Balkan region, and Bulgaria to Asia Minor and the Caucasus region.

30667. CUCUMIS SATIVUS L. **Cucumber.**

From Yarkand, Chinese Turkestan. "(No. 1568a, November 7, 1910.) A local variety of cucumber, called *Baddering.* Said to be small, whitish green, and early. To be tested under irrigation in the hot, arid sections of the United States." (*Meyer.*)

30668. CAPSICUM ANNUUM L. **Red pepper.**

From Yarkand, Chinese Turkestan. "(No. 1569a, November 7, 1910.) A variety of chili pepper of very bright-orange color. Shape medium long, nose blunt, and slightly ribbed. Native name *Kizil mutch.* To be tested like the preceding number (No. 30667)." (*Meyer.*)

30669. OCYMUM BASILICUM L. **Sweet basil.**

From Yarkand, Chinese Turkestan. "(No. 1570a, November 7, 1910.) This is very much grown all through Asia as a garden plant. Occurring in many varieties. Small bunches of the basil are worn on the side of the head, tucked away beneath the headcloth. Some religious meaning seems to be attached to it. Of value as a flavoring herb in regions where it is too warm for mint or thyme." (*Meyer.*)

30670. HORDEUM sp. **Barley.**

From Yarkand, Chinese Turkestan. "(No. 1581a, December 19, 1910.) A hull-less barley of opaque white color, called *Galangatch arpa.*" (*Meyer.*)

30628 to 30671—Continued.

30671. TRITICUM AESTIVUM L. **Wheat.**

From Ism-Salah, Chinese Turkestan. "(No. 1582a, December 6, 1910.) A very large variety of summer wheat, called *Ak-boogdai*. Only a very small quantity obtained." (*Meyer*.)

30672. ANDROPOGON SCHOENANTHUS L. **Lemon grass.**

From Monghyr, Bengal, India. Presented by Mr. Lalit Mohan Sinha, Lalloo Pokhar Road. Received April 25, 1911.

"This is called *Agya Ghas*, or fire-grass, in Hindustani. It is used here with tea as a stimulant and to remove the pain consequent upon catching cold. In cases of sprains and hurts the leaves are made into a paste and applied over the painful part to alleviate the pain. Its oil is also used for the same purpose. It needs an alluvial soil to grow luxuriantly. The roots should be taken out every year after the rains and transplanted in a well-cultivated soft soil. It is not very much cultivated now and is being neglected, but the demand for it is increasing for medicinal use." (*Sinha*.)

Imported for the work of the Office of Drug-Plant, Poisonous-Plant, and Physiological Investigations in cultivating and testing all procurable species of oil-grasses.

Roots.

30673. SAPINDUS sp. **Soapberry.**

From Maison Carree, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria. Received April 25, 1911.

Cuttings.

30674 to 30676.

From Shunking, West China. Presented by Rev. A. E. Evans. Received April 25, 1911.

Cuttings of the following:

30674. CITRUS sp.

30675. PRUNUS sp. **Plum.**

30676. MORUS sp. **Mulberry.**

30677. ZIZIPHUS JUJUBA Miller. **Jujube.**

From Tsining, via Tsinan, Shantung, China. Procured through Dr. Charles H. Lyon. Received April 26, 1911.

"These cuttings are from two trees growing in our compound that bear very nice fruit." (*Lyon*.)

30678. DIOSPYROS KAKI L. f. **Persimmon.**

From Tokyo, Japan. Presented by Miss B. Catherine Pifer. Received April 27, 1911.

"*Shibu kaki*. These grafts are from a species of the Diospyros, or *Mame kaki*, which is known as the best variety for the 'shibu' (juice of fruit). This is the natural fruit and is not edible. This species is found quite frequently in the country." (*Pifer*.)

"'Kaki-no-shibu' is the expressed juice of small, inedible varieties of persimmons. These persimmons are taken about two months before they ripen, i. e., in the middle of August, and crushed—seeds, calyx, and all—in a large stone mortar. Water is added, the juice is strained through coarse linen cloth, and it is then put into a large earthen jar which is closed with a wooden top; paper is pasted over this to make it air-

30678—Continued.

tight, it is placed in a cellar or cave to keep cool, and is ready for use. This fresh-strained juice is simply spread on paper with a brush, which is said to render the paper immune from the attacks of insects as well as less pervious to moisture. Cloth is sometimes treated with this juice, and it is also used for painting stencils, tanning fishing nets, and for other purposes." (*Fairchild.*)

Cuttings.

30679 to 30682. SOLANUM NIGRUM L. **Nightshade.**

From Albano, Stockholm, Sweden. Presented by Dr. Veit Wittrock, director, Botanic Gardens. Received April 26, 1911.

Seeds of the following. Introduced for the purposes of botanical study and breeding work.

30679. Yellow fruited.

30680. Black fruited.

30681. Gold fruited.

30682. Green fruited.

30683. MUSA TEXTILIS Nee. **Manila hemp.**

From Philippine Islands. Presented by Mr. M. M. Saleeby, in charge of fiber plants, Bureau of Agriculture, Manila, through Mr. Lyster H. Dewey. Received March 10, 1911. Numbered April 28, 1911.

Maguindanao.

30684 and 30685. CUCUMIS MELO L. **Muskmelon.**

From the sandy plains near Erivan, Russian Armenia, at the foot of Mt. Ararat. Presented by Mr. W. W. Masterson, American consul, Kharput, Mamuret-ul-Aziz, Turkey, who had them procured by Mr. Alexander Heingartner, American consul, Batum, Russia. Received April 27, 1911.

"These are the finest flavored of any melons I have ever tasted anywhere, and are good to eat from the time they mature in the late summer until some time after Christmas. A particular point in their favor is they are so firm that they can be shipped any distance." (*Masterson.*)

30686 to 30696.

From China. Collected by Mr. George Forrest; presented by Mr. A. K. Bulley, Liverpool, England. Received April 7, 1911.

Seeds of the following; quoted notes by Mr. Forrest:

30686. RHUS VERNICIFERA DC. **Lacquer tree.**

"The lacquer tree of Lichiang Range, western Yunnan."

Distribution.—Southern Asia, extending from the Himalayas in Kashmir, Sikkim, and Bhutan and the Khasi Hills in India eastward through China to Japan; also in the island of Java.

See Nos. 2189, 5016, and 8406 for previous introductions.

30687. PISTACIA CHINENSIS Bunge. **Pistache.**

"Another of the varnish trees of Yunnan, from Langkong Valley at 8,000 feet. Grows from 40 to 80 feet tall."

See Nos. 21970, 24659, and 29499 for previous introductions.

30688. PINUS ARMANDI Franch. **Pine.**

"A tree that reaches a height of 70 to 200 feet. Cones 9 to 12 inches. Fruits edible, sold in all the markets. Chinese name *Song-si*. From Lichiang Range, latitude 27° 20′ N., altitude 9,000 to 10,000 feet."

See No. 27046 for previous introduction.

30686 to 30696—Continued.

30689 to 30692. PRUNUS DOMESTICA L. **Plum.**

30689. "From Lichiang Valley. Small purple plum, damson, good."

30690. "From Lichiang Valley. Golden-drop plum, very fine."

30691. "Same as the preceding."

30692. "Same as the preceding."

30693. (Undetermined.)

"From Lichiang Valley."

Probably belongs to the Solanaceæ.

30694. DIOSPYROS LOTUS L.

"From Lichiang Valley. Tree 20 to 50 feet tall. Flowers yellow. Fruit brown, edible."

See Nos. 27512 and 29486 for previous introductions.

30695. TRACHYCARPUS EXCELSUS (Thunb.) Wendl. **Palm.**

"Common in most valleys. In cultivation for the foliage sheaths, fiber of which is used for ropes, matting, etc."

See Nos. 26907, 27456, 28179, and 28180 for previous introductions.

30696. (Undetermined.)

"From Langkono Plain."

30701. STACHYS SIEBOLDI Miq.

From Paris, France. Purchased from Vilmorin-Andrieux & Co. Received April 29, 1911.

Procured for the experiments of Dr. R. H. True, Office of Drug-Plant, Poisonous-Plant, and Physiological Investigations.

See No. 2195 for description.

30702 and 30703. SOLANUM spp.

From Kingston, Jamaica. Presented by Mr. W. Harris, Superintendent of Public Gardens. Received April 27, 1911.

Seeds of the following:

30702. SOLANUM SEAFORTHIANUM Andrews.

Distribution.—An herbaceous climbing vine found from Venezuela to Guiana, and in the West Indies; cultivated in Panama.

30703. SOLANUM ACULEATISSIMUM Jacquin.

30704 to 30706. CINCHONA spp. **Cinchona.**

From Kingston, Jamaica. Presented by Mr. W. Harris, Superintendent of Public Gardens. Received April 27, 1911.

Seeds of the following:

30704. CINCHONA sp.

Hybrid.

30705. CINCHONA OFFICINALIS L.

Distribution.—A tree growing in the tropical valleys of the Andes in Peru and Bolivia.

30706. CINCHONA SUCCIRUBRA Pavon.

30707. PHOENIX DACTYLIFERA L. **Date.**

From Morocco. Purchased from McCaig, Gilchrist & Co., Glasgow, Scotland. Received April 29, 1911.

Tafilelt. See No. 18630 for description.

30708 and 30709.

From Hermosillo, Mexico. Presented by Mr. Louis Hostetter, American consul. Received April 27, 1911.

Seeds of the following:

30708. CICER ARIETINUM L. **Chick-pea.**

30709. TRITICUM AESTIVUM L. **Wheat.**

30710. SOLANUM CAPSICASTRUM Link.

From Milan, Italy. Presented by Fratelli Ingegnoli. Received April 27, 1911.

Fra Diavolo.

Distribution.—In the grassy plains along the Sapucahi River in the southern part of the province of Minas Geraes in Brazil.

30711. GOSSYPIUM HERBACEUM L. **Cotton.**

From Marash, Turkey. Presented by Mr. Paul N. Nersessian. Received April 26, 1911.

"This is what we call *Native of Marash*. It grows in a conical shape from 1 to 4 feet high, depending on the fertility of the land; usually yields well, that is, produces more bolls to a given area than other varieties, but ordinarily the amount of the lint from a given weight of bolls is less than the other varieties (Nos. 29028 and 29029)." (*Nersessian.*)

30712. MEDICAGO SATIVA L. **Alfalfa.**

From Pishpek, Semiryetschensk, Turkestan, Russia. Presented by Mr. Theo. Kryshtofovich, Russian Government Agricultural Commissioner, St. Louis, Mo. Received May 1, 1911.

30713 to 30736.

From Philippine Islands. Secured by Mr. C. V. Piper, Bureau of Plant Industry. Received April 17, 1911.

Seeds of the following; quoted notes by Mr. Piper:

30713. CANTHAROSPERMUM SCARABAEOIDEUM (L.) Baill.

"A leguminous vine growing in bushes and very fruitful. For testing in Florida."

Distribution.—Throughout the plains of India and up to an elevation of 6,000 feet in the western Himalayas and eastward to China and the Malay Archipelago; also in Madagascar.

30714. BAUHINIA ACUMINATA L.

"According to Mr. Merrill decidedly ornamental. It is a shrub 3 to 6 feet high. To be tested in Florida."

30715. COIX LACHRYMA-JOBI MA-YUEN (Rom.) Stapf. **Job's-tears.**

"This is a variety with soft seeds, cultivated in China and to a slight extent here. It should be tried as a summer grain crop in the United States. Seed can probably be had in quantity from China, but not here."

Distribution.—In the province of Sikkim and on the Khasi Hills in India and eastward through Burma, Cochin China, and Borneo to the Philippines.

30713 to 30736—Continued.

30716. TERAMNUS LABIALIS (L.) Spreng.

"A slender twining legume very abundant in thickets and often matting the ground in fields."

Distribution.—On the plains of India from the foot of the western Himalayas to Ceylon; generally naturalized throughout the Tropics and in Natal, South Africa.

30717. ARACHIS HYPOGAEA L. **Peanut.**

From Jolo.

30718 to 30720. RICINUS COMMUNIS L. **Castor bean.**

30718. From Negros Occidental.

30719. From Iloilo.

30720. From Iloilo.

30721 to 30726. VIGNA SINENSIS (Torner) Savi. **Cowpea.**

(Hasskarl, Catalogus Plantarum in Horto Botanico Bogoriensi, 1844, p. 279.)

The cowpea up to this time has been listed in these Inventories as *Vigna unguiculata* (L.) Walpers. Mr. C. V. Piper, in Bulletin 229, Bureau of Plant Industry, United States Department of Agriculture, p. 143, has identified the type specimen of *Dolichos unguiculatus* L. in the Linnæan Herbarium, on which *Vigna unguiculata* (L.) Walpers is based, as a species of Phaseolus which Urban in 1905 redescribed as *Phaseolus antillanus*. Apparently, therefore, the first name applied to the cowpea is *Dolichos sinensis* Torner (Centuria II. Plantarum, 1756, p. 28; reprinted in Linnæus's Amoenitates Academicae, vol. 4, 1759, p. 326), on which is based the name here used.

30721. Mixed, buff, and reddish brown seed contained in this lot. From Iloilo.

30722. Mixed, buff, and reddish brown seed contained in this lot. From Negros Occidental.

30723. Blackeye. From Jolo.

30724. Marbled reddish brown. From Negros Occidental.

30725. Black. From Jolo.

30726. Black. From Jolo.

30727 to 30730. PHASEOLUS CALCARATUS Roxb.

30727. Black.

30728. Greenish tan.

30729. Reddish brown.

30730. Brown and tan seeds mixed.

All of the above are from Iloilo.

30731 to 30733. PHASEOLUS RADIATUS L. **Adsuki bean.**

30731. Brown. From Moro Province.

30732. Green. From Jolo.

30733. Golden. From Iloilo.

30734 and 30735. CAJAN INDICUM Spreng. **Pigeon pea.**

30734. Black. From Iloilo.

30735. White. From Ilocos Sur.

30736. CHAETOCHLOA FLAVA (Nees) Scribner. **Millet.**

From Jolo.

30737. CITRUS LIMONUM Risso. **Lemon.**

From the Salvation Army Industrial Farm at Ani, Dalash P. O., via Simla, India. Grown at an elevation of 4,000 feet in the famous Kulu Valley in the Himalayas. Presented by Mr. F. Booth Tucker, Salvation Army, Simla, India. Received May 3, 1911.

"The trees and fruit from which these seeds were taken are very fine. I may add that we have had a particularly severe winter, with a considerable fall of snow in the valley. Our oranges and lemons were a good deal damaged by a hailstorm, but not by the accompanying frost and snow." (*Tucker.*)

30738. MEDICAGO SATIVA L. **Alfalfa.**

From Punjab, India. Presented by Mr. A. C. Hartless, superintendent, Government Botanical Gardens, Seharunpur, United Provinces, India. Received May 2, 1911.

"Received from the Economic Botanist, Punjab, who writes that it is the best variety grown in that province." (*Hartless.*)

30739. SOLANUM NIGRUM L. **Nightshade.**

From Isla de Pinos. Presented by Rev. Cal. Ogburn, Los Angeles, Cal. Received March 10, 1911. Numbered May 3, 1911.

Introduced for purposes of botanical study and breeding work.

30740. SOLANUM NIGRUM L. **Nightshade.**

From Chico, Cal. Received through Mr. R. L. Beagles, special agent acting in charge, Plant Introduction Garden. Received April, 1911. Numbered May 3, 1911.

Introduced for the same purposes as the above.

30741. OLEA EUROPAEA L. **Olive.**

From Sfax, Tunis. Purchased from Chatel & Jacquemart, through Mr. T. H. Kearney. Received May 2, 1911.

Chemlali. See Nos. 22762 and 22763 for previous introduction.

Truncheons.

30742. ANACARDIUM EXCELSUM (Bertero and Balbis) Skeels.

(*Rhinocarpus excelsa* Bertero and Balbis; Humboldt, Bonpland, and Kunth, Nova Genera et Species Plantarum, vol. 7, 1825, p. 6, pl. 601.)

(*Anacardium* (?) *rhinocarpus* DC., Prodromus, vol. 2, 1825, p. 62.)

This Colombian tree, closely related to the cashew nut, was first named *Rhinocarpus excelsa* by Humboldt, Bonpland, and Kunth in 1825, and was afterwards placed in the genus Anacardium by De Candolle, who used the generic name of the original authors for his specific name. The binomial *Anacardium excelsum*, which is the correct name for the species according to present rules of nomenclature, seems never to have been published.

Anacardium excelsum is a tall tree found in the valley of the Magdalena River in northern Colombia, in the vicinity of Caracas in Venezuela, and in Panama and San Salvador.

From San Jose, Costa Rica. Presented by Mr. C. Wercklé, Department of Agriculture. Received May 3, 1911.

This Costa Rican species of cashew is recommended by Mr. O. F. Cook for trial as a stock for the mango in Florida.

30743. COLOCASIA sp. **Dasheen.**

From Mukden, Manchuria. The region of production not exactly known, but said to be in the northern part of Chihli Province, China. Procured by Mr. Edward C. Parker, agriculturist, Bureau of Agriculture, Industry, and Commerce. Received May 3, 1911.

"*Taro.* Chinese name *Yu to.*" (*Parker.*)

"The tubers received were small and resembled those of the Japanese dasheens. They are mucilaginous and lacking in flavor when cooked. The tubers are nonacrid even when uncooked." (*R. A. Young.*)

30744 to 30748.

From Wulukai, 20 miles north of Kirin, the capital of Kirin Province, Manchuria, 44° north latitude. Procured by Mr. Edward C. Parker, agriculturist, Bureau of Agriculture, Industry, and Commerce, Mukden, Manchuria. Received May 3, 1911.

Seeds of the following; quoted notes by Mr. Parker:

"Wulukai is the center of one of the most famous and fertile soil areas of north Manchuria. The climate is one of great extremes, temperatures ranging from 42° below zero Fahrenheit to 96° above zero. Killing frosts occur occasionally as late as May 10 and may reoccur after September 20. This district is said to have been partially settled for 75 years and the varieties of beans are reputed to be of the same age."

30744 to 30747. GLYCINE HISPIDA (Moench) Maxim. **Soy bean.**

30744. "Black-eyebrow soy bean. Chinese name *Hei mei tou.* This variety is classified by the Chinese as being medium late in date of maturity."

30745. Yellow. "White-eyebrow soy bean. Chinese name *Pei mei tou.* This variety is classified by the Chinese as being late in the date of maturity."

30746. Yellow. "Compact, round soy bean. Chinese name *Chin yuan tou.* This variety is classified by the Chinese as being late in date of maturity."

30747. "Big black soy bean. Chinese name *Tah hei tou.* This variety is classified by the Chinese as being very early in date of maturity. It is used principally as a feed for work horses and mules, also for bean curd and for oil production."

30748. PHASEOLUS RADIATUS L. **Mung bean.**

"Small green food bean. Chinese name *Hsiao liu tou.* Classified by the Chinese as being medium late in date of maturity. This variety is doubtless from the same stock as No. 28053. It is grown everywhere in Manchuria for human food, being boiled with kowliang or millet and also ground into meal, mixed with kowliang meal and made into vermicelli."

30749. IPOMOEA BATATAS (L.) Poir. **Sweet potato.**

From Auckland, New Zealand. Presented by Arthur Yates & Co. Received May 4, 1911.

"The New Zealand kumara has been chiefly grown by our native race, the Maori, and consequently any varieties which may have been distinct in the first place have long since become crossed so that it is now impossible to obtain separate sorts. The tubers sent are of the kumara which is known here as the New Zealand red-skinned kumara. This is a New Zealand variety which is in common use here." (*Yates & Co.*)

30750. NICOTIANA TABACUM L. **Tobacco.**

From Rosa Morada, Acaponeta District, Tepic, Mexico. Presented by Mr. Lauro Liadas, Director General of Agriculture, Mexico, Mexico. Received May 4, 1911.

"*Papantla.*"

30751. COLOCASIA sp. **Dasheen.**

From Arimao, Cuba. Presented by Mr. Robert M. Grey, Harvard Botanical Station, Central Soledad, Cienfuegos, Cuba. Received May 8, 1911.

"A dasheen of good quality. When cooked it is mealy and nearly white." (*R. A. Young.*)

30752. ZINZIBER OFFICINALE Rosc. **White ginger.**

From Tsining, via Tsinan, Shantung, China. Presented by Dr. C. H. Lyon. Received May 3, 1911.

30753 to 30763.

From Edinburgh, Scotland. Presented by Dr. Isaac Bailey Balfour, director, Royal Botanic Gardens. Received April 25, 1911.

Seeds of the following:

30753. BERBERIS VIRESCENS Hook. f. **Barberry.**

For previous introduction see No. 27122.

30754. BUDDLEIA ALBIFLORA Hemsl.

Distribution.—The Patung district in the province of Hupeh, China.

30755. LUPINUS ARBOREUS Sims.

30756. LUPINUS POLYPHYLLUS Lindl.

30757. LUPINUS POLYPHYLLUS Lindl.

Variety *moerheimi.*

30758. SCHIZONOTUS AITCHISONI (Hemsl.) Skeels.

(*Spiraea aitchisoni* and *Sorbaria aitchisoni* Hemsley, Gardeners' Chronicle, ser. 3, vol. 28, 1900, p. 254.)

This spirealike shrub from Afghanistan was named *Spiraea aitchisoni* by Dr. Hemsley, but in closing the article he remarks as follows: "There is also a difference of opinion as to the limits of the genus Spiraea. The name Sorbaria was long ago proposed for *S. sorbifolia;* and *S. lindleyana, S. grandiflora,* and *S. kirilowi* belong to the same group. Taking this view, our plant would have to be called *Sorbaria aitchisoni.*" The generic name Sorbaria was published by A. Braun (Ascherson, Flora Brandenburg, p. 177) in 1864, with one species *Sorbaria sorbifolia,* based on *Spiraea sorbifolia* L. But in 1830 Lindley (Introduction to the Natural System of Botany, p. 81) established the genus Schizonotus, also based on *Spiraea sorbifolia* L. It is therefore necessary to use the binomial proposed above.

Schizonotus aitchisoni was first discovered by Dr. Aitchison in the valley of the Kuram River in Afghanistan at elevations of 7,000 to 9,000 feet and has also been reported from the province of Kashmir in northern India.

30759. CLETHRA ARBOREA Solander.

Distribution.—A small tree with elliptical, serrate leaves and fragrant white flowers in spicate racemes, found in the Madeira Islands.

30753 to 30763—Continued.

30760. Gloriosa superba L.

Distribution.—Throughout tropical India from the northwestern Himalayas to Ceylon and eastward to Malakka and Cochin China; also in the Mozambique district of eastern Africa and in Guinea on the western coast.

30761. Cajuputi hypericifolia (Salisb.) Skeels.

(*Metrosideros hypericifolia* Salisb. Prodromus, 1796, p. 351).

The seeds of this Australian shrub belonging to the family Myrtaceæ were received under the name *Melaleuca hypericifolia* Smith (Transactions of the Linnean Society, vol. 3, 1797, p. 279). The generic name Melaleuca was published by Linnæus (Mantissa Plantarum, p. 105) in 1767, with one species, *M. leucadendra*, based on *Myrtus leucadendra* Stickman (Herbarium Amboinense, 1754, p. 9; reprinted in Linnaeus's Amoenitates Academicae, vol. 4, 1759, p. 120). However, in 1763, Adanson (Familles des Plantes, vol. 2, pp. 84, 530) had published the generic name Cajuputi, based on plate 16 of volume 2 in Rumph's Herbarium Amboinense, the same plate on which *Myrtus leucadendra* was founded. It is therefore necessary to use the generic name Cajuputi for the species congeneric with *Myrtus leucadendra* Stickman. This course has already been adopted by Lyons (Plant Names, Scientific and Popular, 1900, p. 74); see No. 30793.

Distribution.—A tall shrub with rich red flowers in spikes 2 inches long, found in damp places in the vicinity of Port Jackson in New South Wales, Australia.

30762. Primula bulleyana Forrest. **Primrose.**

30763. Primula littoniana Forrest. **Primrose.**

30764 to 30822.

From Cambridge, England. Presented by Dr. R. Irwin Lynch, curator, University Botanic Garden, Cambridge University. Received April 25, 1911.

Seeds of the following:

30764. Clematis integrifolia × viticella. **Clematis.**

See No. 29927 for previous introduction.

30765. Clematis graveolens Lindl. **Clematis.**

Distribution.—On the temperate slopes of the western Himalayas at an elevation of 6,000 to 11,000 feet in northern India.

30766. Clematis heracleaefolia DC. **Clematis.**

Distribution.—On the slopes of the mountains in the provinces of Chihli and Shantung, China.

30767. Clematis integrifolia L. **Clematis.**

See No. 28844 for previous introduction.

30768. Clematis recta L. **Clematis.**

Distribution.—Southern Europe extending from northern Spain to central Russia.

30769. Berberis lycium Royle. **Barberry.**

See No. 1603 for previous introduction.

Distribution.—On the dry, hot slopes of the Himalayas at an elevation of 3,000 to 9,000 feet in the northwestern part of India.

30770. × Berberis stenophylla Lindl.

30764 to 30822—Continued.

30771. CRAMBE CORDIFOLIA Stev.

Distribution.—An herbaceous perennial found in desert places at the foot of the northern slope of the Caucasus Mountains in the vicinity of Pyatigorsk and Mozdok, Russia.

30772. PITTOSPORUM CRASSIFOLIUM Solander.

Distribution.—Along the shores of the islands of New Zealand.

30773. PITTOSPORUM HETEROPHYLLUM Franchet.

Distribution.—A shrub 6 to 12 feet high growing on slopes of limestone mountains at an altitude of 7,000 feet in the province of Yunnan, China.

30774. CEANOTHUS VEITCHIANUS Hook.

Apparently a hybrid between some of the species native to the region around San Francisco Bay, Cal.

30775. CORIARIA TERMINALIS Hemsl.

Distribution.—A shrub found on the frontier between the province of Szechwan, China, and Tibet, and in Sikkim in northern India, at an altitude of 9,000 to 13,000 feet.

30776. ACACIA CAESIA (L.) Willd.

Distribution.—On the lower slopes of the Himalayas in the province of Behar and in Burma in India, and in the Malay Archipelago.

30777. ACACIA CYCLOPS Cunningham.

Distribution.—In the region around King George Sound and in the valleys of the Swan and Preston rivers in West Australia.

30778. ACACIA HAKEOIDES Cunningham. **Western black wattle.**

Distribution.—Along the Lachlan and Severn Rivers in New South Wales, and in the Murray Desert in Victoria, Australia.

30779. ACACIA LEPTOCLADA Cunningham.

Distribution.—In New South Wales and on the eastern coast of Queensland in Australia.

30780. ACACIA LONGIFOLIA (Andr.) Willd.

See No. 26304 for previous introduction.

30781. ACACIA NERIIFOLIA Cunningham.

See No. 10477 for previous introduction.

Distribution.—In open forests on the Balonne River in Queensland, and in New South Wales and South Australia.

30782. ACACIA PENNINERVIS Sieb.

See No. 1827 for previous introduction.

Distribution.—Rocky slopes of the mountains in the provinces of Queensland, New South Wales, and Victoria, Australia, and in the island of Tasmania.

30783. ACACIA SPECTABILIS Cunningham. **Mudgee wattle.**

See No. 1838 for previous introduction.

Distribution.—In the river valleys of Queensland and New South Wales, Australia.

30784. CARAGANA ARBORESCENS Lam. **Siberian pea tree.**

See No. 29960 for previous introduction.

30785. CARAGANA ARBORESCENS Lam. **Siberian pea tree.**

Variety *pendula.*

30764 to 30822—Continued.

30786. COLUTEA ARBORESCENS L. **Bladder senna.**

See No. 1570 for previous introduction.

Distribution.—Southern Europe, western Asia, and northern Africa, extending from France and Germany eastward to Syria.

30787. COLUTEA ORIENTALIS Miller.

Distribution.—On stony hillsides in the Caucasus region of southeastern Russia and extending eastward through northern Persia to Turkestan.

30788. ROSA DAMASCENA Miller **Rose.**

30789. ROSA CANINA L. **Rose.**

See No. 26265 and 28236 for previous introductions.

30790. ROSA MACROPHYLLA Lindl. **Rose.**

See No. 28239 for previous introduction.

30791. SCHIZONOTUS AITCHISONI (Hemsl.) Skeels.

See No. 30758 for previous introduction.

30792. ULMARIA FILIPENDULA (L.) Hill.

Distribution.—In meadows, pastures, and open woods of Europe and Asia, extending eastward to Dzungaria and the Altai Mountains.

30793. CAJUPUTI ERICIFOLIA (Smith) Lyons. **Bottle-brush tea-tree.**

Distribution.—A tall shrub or small tree growing in swampy ground along streams or near the sea in the provinces of New South Wales and Victoria, Australia, and in Tasmania.

30794. CAJUPUTI HYPERICIFOLIA (Salisb.) Skeels.

30795. CAJUPUTI PUBESCENS (Schauer) Skeels.

(*Melaleuca pubescens* Schauer, in Walpers' Repertorium, vol. 2, 1843, p. 928.)

The reason for the use of the generic name Cajuputi for the plants usually known as Melaleuca is explained under No. 30761.

Distribution.—A tall shrub or small tree found along the banks of streams in Victoria and South and West Australia, Australia.

30796. CARUM CARVI L. **Caraway.**

See No. 26445 for previous introduction.

30797. COREOPSIS TINCTORIA Nuttall.

See No. 12975 for previous introduction.

30798. DAHLIA GRACILIS Ortegies. **Dahlia.**

See No. 28216 for previous introduction.

30799. DAHLIA MERCKII Lehm. **Dahlia.**

See Nos. 21554 and 21555 for previous introductions.

Distribution.—In the region of San Luis Potosi in northern Mexico, and on the summit of a mountain near Guadalupe in southern Mexico.

30800. SENECIO VEITCHIANUS Hemsl.

Distribution.—A yellow-flowered herbaceous perennial found in bogs and wet places at an altitude of 4,000 to 6,000 feet in the province of Hupeh, China.

30801. PRIMULA KEWENSIS Hort. **Primrose.**

A hybrid of garden origin between *Primula floribunda* and *P. verticillata.*

30764 to 30822—Continued.

30802. FRAXINUS EXCELSIOR L. **Ash.**

Distribution.—Throughout central and northern Europe and in the Caucasus region of western Asia.

30803. FRAXINUS EXCELSIOR L. **Ash.**

Variety *pendula.*

30804. BUDDLEIA ALBIFLORA Hemsl.

30805. BUDDLEIA HEMSLEYANA Koehne.

Distribution.—In the provinces of Hupeh and Szechwan, China.

30806. BUDDLEIA VARIABILIS Hemsl.

Distribution.—A shrub growing on the slopes of the mountains up to 6,000 feet in the provinces of Hupeh and Szechwan, China.

30807. VERONICA SALICIFOLIA Forster.

Distribution.—A shrub from 3 to 15 feet high growing from sea level to 3,500 feet elevation in the islands of New Zealand.

30808. VISCUM ALBUM L. **Mistletoe.**

See No. 24666 for previous introduction.

30809. PTEROCARYA FRAXINIFOLIA (Lam.) Spach. **Caucasian walnut.**

Distribution.—A tree found in the woods bordering on the southern parts of the Black and Caspian seas, and in the northern part of Persia.

See No. 27768 for previous introduction.

30810. PTEROCARYA STENOPTERA DC. **Wing nut.**

See No. 6609 for previous introduction.

Distribution.—On mountain slopes in the provinces of Kiangsu, Chekiang, Kiangsi, Hupeh, Szechwan, Yunnan, and Kwangsi, China.

30811 and 30812. BETULA NANA L. **Birch.**

30811. Variety *crenata.* **30812.** Variety *pendula.*

30813. LARIX DAHURICA Turcz. **Siberian larch.**

Variety *pendula.*

30814. LARIX LEPTOLEPIS (Sieb. and Zucc.) Gord. **Japanese larch.**

See No. 6672 for previous introduction.

Distribution.—Slopes of the mountains in northern and central Japan extending from Hokushu (Yezo) southward to the region around Yokohama.

30815. PINUS HALEPENSIS Miller. **Pine.**

Distribution.—On dry hills in the countries bordering on the Mediterranean from Portugal to Syria and in northern Africa.

30816. ALPINIA MUTICA Roxb.

Distribution.—An herbaceous perennial with large white flowers variegated with red and yellow, found in the Malay Peninsula and in the Malay Archipelago.

30817. IXIOLIRION TATARICUM (Pall.) Herbert.

Distribution.—A bulbous herbaceous perennial growing from the Caucasus region eastward through southern Siberia and Turkestan to Dzungaria.

30818. ASPARAGUS CRISPUS Lam. **Asparagus.**

See No. 30219 for previous introduction.

30764 to 30822—Continued.

30819. ASPARAGUS SCANDENS DEFLEXUS Baker. **Asparagus.**

See No. 29120 for previous introduction.

30820. LIVISTONA HOOGENDORPII Andre. **Palm.**

See No. 9724 for previous introduction.

Distribution.—A palm from the island of Java.

30821. AGROSTIS CANINA L. **Rhode Island bent-grass.**

See No. 18413 for previous introduction.

30822. DACTYLIS GLOMERATA L. **Orchard grass.**

30823. GOSSYPIUM BARBADENSE L. Cotton.

From Alexandria, Egypt. Presented by Mr. D. S. Fish, secretary, Horticultural Society. Received May 16, 1911.

Sakellaridis. "This variety is of quite recent introduction and produces the best Egyptian cotton. The seed sent is said to have been saved from selected plants." (*Fish.*)

30824. MUCUNA IMBRICATA DC.

From Calcutta, India. Presented by Maj. A. T. Gage, superintendent, Royal Botanic Garden. Received May 23, 1911.

Distribution.—In the tropical region of India, rising to an elevation of 4,000 feet in the eastern Himalayas.

30825 to 30827. VITIS VINIFERA L. Grape.

From Tiflis, Caucasus, Russia. Presented by Mr. A. Rolloff, Botanic Garden. Received May 6, 1911.

Cuttings of the following:

30825. *Mskhali.* A dessert variety. Does well in alkaline soils. Ripens from September 1 to 15.

30826. *Bandi.* Fruitful dessert variety. May be kept until Easter.

30827. *Schafei.* This appears to be the same as the Shafai, No. 27621; see this number for description.

30828. MUSA sp. Banana.

From Pirapo, Paraguay. Presented by Mr. C. F. Mead. Received May 6, 1911.

"Paraguayan banana, botanical name unknown unless it is a sport from *Musa sapientium.* Grows to a height of 20 to 25 feet, very large and heavy leaves which are raveled easily by the wind, making a dirty and unpopular plant. Fruit in very large bunches up to 100 pounds in weight and classed by many travelers as the finest flavored of all bananas, which is my opinion also as compared with Hawaiian, Mexican, Central American, and Brazilian varieties." (*Mead.*)

30829 and 30830. MEDICAGO spp. Alfalfa.

From Russia. Received through Mr. Frank N. Meyer, agricultural explorer, May 3, 1910. Numbered May 8, 1911.

Plants of the following:

30829. From near Yelisavetpol, Caucasus, Russia.

"(No. 756, April 7, 1910.) An alfalfa growing wild along banks of ravines, in open plains, and along roads, in rather heavy, clayey soil. Much sought for by grazing cattle and horses, who grow fat on it. Called by local German

30829 and 30830—Continued.

30829—Continued.

settlers *Steinklee*. Apparently of value as a fodder plant in semiarid regions." (*Meyer*.)

30830. From near Helenendorf, Caucasus, Russia.

"(No. 757, April 5, 1910.) A perennial alfalfa growing on limey, clayey soil along banks and on ridges; makes very long roots and is apparently drought resistant. Called by local German settlers *Steinklee*. Of value like the preceding number." (*Meyer*.)

30831 and 30832. PHORMIUM spp. **New Zealand flax.**

From Greendale, Canterbury, New Zealand. Presented by Mr. T. W. Adams. Received May 6, 1911.

Seeds of the following; notes by Mr. Adams:

30831. PHORMIUM TENAX Forst.

"Seeds of several varieties that I have growing here, some of them are ornamental and all are good fiber sorts."

30832. PHORMIUM COOKIANUM Le Jolis.

"This variety is ornamental in flower and fruit, but poor as a fiber plant."

30833. ENTELEA ARBORESCENS R. Brown. **Whau.**

From Epsom, Auckland, New Zealand. Presented by Mr. W. Petrie. Received May 6 and 9, 1911.

"This plant is not a hardy one and will barely withstand even slight frosts. It is most plentiful on small coastal islands in the northern part of New Zealand, and at the upper slopes of wooded gullies above the fog line in autumn and winter. The seed grows most readily in my garden; indeed, seedlings are quite a weed." (*Petrie*.)

"This plant is greedily eaten by cattle and horses, and consequently is becoming rare fast on the mainland, except in comparatively inaccessible situations. It is still plentiful on most of the small outlying islands on the northeast coast of the Auckland district, often exhibiting great luxuriance. On Cuvier Island I measured leaves with petioles 2 feet long, with a blade 1 foot 6 inches in diameter." (*Cheeseman, Manual New Zealand Flora, p. 83, 1906*.)

"This introduction is a tree already tried in California and found to be a very rapid grower. It is made for the purpose of ascertaining the possibility of using the sawdust of the wood, which is very soft and light, as packing for grapes in place of the cork and redwood sawdust commonly used." (*S. C. Stuntz*.)

30834. ENTELEA ARBORESCENS R. Brown. **Whau.**

From Auckland, New Zealand. Presented by Mr. E. Clifton, director, Department of Agriculture, Commerce, and Tourists, Wellington, New Zealand. Received May 9, 1911.

See No. 30833 for description.

30835. ANNONA SENEGALENSIS Pers. **Annona.**

From Sacikela, Angola, West Africa. Presented by Mr. Merlin W. Ennis, Benguela, West Africa, via Lisbon. Received May 9, 1911.

"Seeds of a dwarf annona. The plant is about the size of the huckleberry and favors about the same sort of soil and location. The fruit is the size of a small apple, and some have a decidedly pleasant taste. In its wild state the plant is killed down every year by the fires, so I think it could be grown anywhere in the South where the ground does not freeze." (*Ennis*.)

See No. 25169 for previous introduction.

30836 to 30838.

From Nice, France. Presented by Dr. A. Robertson Proschowsky. Received May 1, 1911.

Quoted notes on the following by Dr. Proschowsky:

30836. SOLANUM NIGRUM L. **Nightshade.**

"This plant at Nice is in flower and fruit any time of the year."

Seeds.

30837. CITRUS sp.

"*Poire du Commandeur.* An agrume (a citrus fruit) forming a very beautiful tree, with its large pear-shaped fruits, which are of a pleasantly acid flavor and furnish a good lemonade."

Seeds.

30838. OPUNTIA sp.

"This is a fruit of great merit, most agreeable and refreshing, and if not bruised keeps in good state all through the winter."

Cuttings.

30839 to 30841. GLYCINE HISPIDA (Moench.) Maxim. Soy bean.

From Bengal, India. Presented by Mr. E. J. Woodhouse, Department of Agriculture. Received May 9, 1911.

Seeds of the following:

30839. Black.

30840. Yellow.

30841. Chocolate.

"These varieties of soy beans are cultivated to a very small extent on the plains of Bengal, mostly north of the Ganges. They have probably spread outward from the Himalayas, as their vernacular name, *Bhetmas*, is the same as that used by the Bhutias. They have been grown here for two years and breed true; they have been analyzed by Mr. C. S. Taylor, agricultural chemist to the government, who finds that the black-seeded variety yields an average of 38.4 per cent of proteid (N×6.3), the yellow variety 36.5, and the chocolate 32.6. They are all decumbent plants with small violet flowers and with the upright end of the branches more twining. The black-seeded variety is not so tall growing and has rather smaller bullate leaves, so that it can be easily distinguished in the field from the other two varieties. Plate II, fig. 2, of Bulletin 197, Bureau of Plant Industry, U. S. Department of Agriculture, gives a fair idea of the vegetative stage of the chocolate and yellow seeded varieties.

"The seeds are sown here in June at the break of the monsoon and are harvested in December. The plants die out very easily if water-logged early in growth and yield badly if the moisture fails at the flowering season." (*Woodhouse.*)

30842. HORDEUM VULGARE L. Hull-less barley.

From Cawnpore, United Provinces, India. Presented by Mr. H. Martin Leake, Land Records and Agriculture. Received May 1, 1911.

30843. SAPOTA ZAPOTILLA (Jacq.) Coville. Sapodilla.

From Christiansted, St. Croix, Danish West Indies. Presented by Mr. A. J. Blackwood, American consular agent. Received May 10, 1911.

"This pear-shaped variety is considered the finest flavored and best grown in the island." (*Blackwood.*)

Plants.

30844 to 30867.

From Sapporo, Japan. Presented by Prof. T. Minami, Botanic Garden, College of Agriculture, Tohoku Imperial University. Received May 9, 1911.

Seeds of the following:

30844. ACER DIABOLICUM Bl. **Maple.**

Distribution.—In the islands of Honshu (Hondo) and Kiushu in Japan.

30845. ACER UKURUNDUENSE Trautv. and Meyer. **Maple.**

Distribution.—The Amur region of Manchuria, the island of Sakhalin, and the islands of Hokushu (Yezo) and Honshu (Hondo) in Japan.

30846. BERBERIS KOREANA Palibin. **Barberry.**

Distribution.—Known only from the vicinity of Seoul, in Chosen (Korea).

30847. VIBURNUM SARGENTI Koehne.

Distribution.—A shrub resembling *Viburnum opulus* L., found in the vicinity of Peking, China, and also in Japan.

30848. CERCIDIPHYLLUM JAPONICUM Sieb. and Zucc.

Distribution.—A deciduous, bushy tree found in the woods on the mountain slopes in Japan from Hokushu (Yezo) to Kiushu.

30849. LEUCOTHOE GRAYANA Maxim.

Distribution.—An ornamental, low, half-evergreen shrub found on wooded slopes in the islands of Japan.

30850. RHODODENDRON ALBRECHTI Maxim.

Distribution.—In the wooded subalpine valleys of the volcanic mountains of Japan.

30851. VACCINIUM BUERGERI Miq.

Distribution.—In the woods on the mountain slopes of northern and central Japan.

30852. VACCINIUM CILIATUM Thunb.

Distribution.—A much-branched shrub cultivated generally in Japan; probably wild in the province of Bitchu.

30853. VACCINIUM JAPONICUM Miq.

Distribution.—In the woods on the alpine slopes of the mountains in the island of Japan.

30854. VACCINIUM VITIS-IDAEA L. **Cowberry.**

30855. AKEBIA LOBATA Decaisne.

See Nos. 24744 and 26424 for previous introductions.

30856. PICEA ABIES (L.) Karst. **Norway spruce.**

30857. CRATAEGUS JOZANA Schneider.

Distribution.—In the island of Hokushu (Yezo), in northern Japan.

30858. ERIOBOTRYA JAPONICA (Thunb.) Lindl. **Loquat.**

30859. PRUNUS INCISA KURILENSIS (Miyabe) Koidzumi.

Distribution.—A straggling shrub found on exposed hilltops in the Kuril islands.

30860. PRUNUS MAXIMOWICZII Rupr.

Distribution.—Eastern Manchuria, Sakhalin Island, and in Japan.

30861. PRUNUS PSEUDO-CERASUS Lindl. **Flowering cherry.**

30844 to 30867—Continued.

30862. RHODOTYPOS KERRIOIDES Sieb. and Zucc.

30863. ROSA MULTIFLORA Thunb. **Rose.**

Variety.

30864. PHELLODENDRON SACHALINENSE Sargent.

"Of the three species of this genus established in the Arboretum, *Phellodendron sachalinense* is the handsomest. All the species are natives of eastern Asia and are small trees with pinnate leaves, small clusters of inconspicuous yellow flowers, the male and female flowers being produced on different individuals, and black berrylike fruits. They have bright yellow wood and roots, and all parts of these trees are permeated with a fragrant aromatic oil, which apparently makes them immune from the attacks of insects. *P. sachalinense*, which is a native of Sakhalin and the northern island of Japan, has grown in the Arboretum into a tree about 30 feet high, with a tall, straight trunk and wide-spreading branches, forming a shapely, flat-topped head. The seedlings springing up naturally near the old trees indicate that it is likely to hold its own in New England. The hardiness of this tree, its rapid growth, and the fact that it is not injured by insects suggest that this is a good subject to plant in narrow streets." (*Bulletin of Popular Information, No. 7, Arnold Arboretum, Harvard University.*)

Distribution.—An ornamental deciduous tree found in the vicinity of Seoul, Chosen (Korea), the southern part of the island of Sakhalin, and in the vicinities of Sapporo and Hakodate in the island of Hokushu (Yezo), Japan.

30865. DIGITALIS LUTEA L. **Foxglove.**

Distribution.—In gravelly places in southern Europe, extending from France and Italy eastward to Greece.

30866. ULMUS GLABRA Miller. **Elm.**

Variety *japonica*. "This form very much resembles the American elm in habit, foliage, and pubescence, but the flowers and fruits are like those of *U. campestris*." (*Bailey's Cyclopedia of American Horticulture.*)

Distribution.—In woods and copses on the alpine slopes of Japanese mountains.

30867. CLERODENDRUM TRICHOTOMUM Thunb.

"A very handsome, hardy shrub. In the north it kills to the ground but sprouts up if the crown is protected." (*Bailey's Cyclopedia of American Horticulture.*)

Distribution.—In clumps of shrubbery on the margin of woods in the vicinity of Yokosuka in central Japan, and southwestward to Nagasaki on the island of Kiushu.

30868 to 30880.

From Philippine Islands. Received through Mr. C. V. Piper, Bureau of Plant Industry, May 4, 1911.

Seeds of the following; quoted notes by Mr. Piper:

30868. AGATI GRANDIFLORA (L.) Desv.

(*Sesbania grandiflora* Poir.; *Robinia grandiflora* L.)

"*Gawi-gawi*. A very rapid-growing tree 15 to 20 feet high producing abundant flowers and seed. The flowers are fleshy and are eaten as salad by the natives. Used for shade and windbreaks."

30868 to 30880—Continued.

30869. VITIS BARBATA Wall. **Grape.**

"A native grape."

Distribution.—On the Khasi Hills ascending to an elevation of 3,000 feet, and in the provinces of Assam, Sylhet, Pegu, and Tenasserim in India.

30870. OPERCULINA TURPETHUM (L.) Manso.

"A morning-glory with large white flowers and much-inflated pods. Quite ornamental."

Distribution.—Throughout India and extending southeastward through the Malay Archipelago and Polynesia to Australia.

30871. IPOMOEA sp. **Morning-glory.**

"A morning-glory with rather small yellow flowers."

30872. IPOMOEA sp. **Morning-glory.**

"A slender native morning-glory."

30873. MEIBOMIA LASIOCARPA (Beauv.) Kuntze.

"A species 3 to 5 feet high producing abundant seed in dense clusters."

Distribution.—From the Himalayas, where it ascends to an elevation of 4,000 feet, through India, Ceylon, and the Malay Archipelago to the Philippines, and in Madagascar and tropical Africa.

30874. MEIBOMIA GANGETICA (L.) Kuntze.

"A species 3 to 4 feet high, the seed not very abundant."

Distribution.—Throughout the Tropics of the Eastern Hemisphere from Africa and India eastward to China and Australia.

30875. MEIBOMIA PULCHELLA (L.) Kuntze.

"A half-shrubby species, 3 to 6 feet high, producing abundant seed."

Distribution.—From the eastern Himalayas in India southwestward to Ceylon, and in China and the Malay Archipelago to the Philippines.

30876. INDIGOFERA NIGRESCENS Kurz.

"An annual legume with pink flowers and abundant seed. Grows 1 to 4 feet high. Herbage odorous and not eaten by cattle. To be tested as a green-manure plant in Florida and Biloxi, Miss."

Distribution.—On the slopes of the Khasi Hills in India and in the southwestern part of the province of Yunnan, China.

30877. INDIGOFERA NIGRESCENS Kurz.

"A legume 1 to 4 feet high, quite erect. Annual, perhaps of value for green-manure crop."

Distribution.—Same as the preceding number.

30878. MOGHANIA MACROPHYLLA (Willd.) Kuntze.

"An erect, stout legume, 3 to 7 feet high, quite leafy but with coarse stems. The pods are produced in dense clusters. Try for forage and green manure."

Distribution.—From the central Himalayas in northern India southwestward to Ceylon, and in Malakka, southern China, and the Malay Archipelago to the Philippines.

30879. CANAVALI TURGIDUM Graham.

"A seashore species, climbing the trees to a height of 20 feet. Not eaten by the natives. It is closely related to *Canavali obtusifolium* (*C. lineata*).

30868 to 30880—Continued.

30880. SESBAN CANNABINUM (Retz.) Poir.

"An annual legume 3 to 9 feet high. Much like *Sesban macrocarpa*."

Distribution.—In the Tropics of the Eastern Hemisphere from India to the Philippines.

30881. TRIFOLIUM PRATENSE L. **Red clover.**

From England. Presented by Prof. H. T. Güssow, Dominion Botanist, Central Experimental Farm, Department of Agriculture, Ottawa, Canada. Received May 13, 1911.

"*Leighton's Inherited Permanent* red clover. Leighton claims that by careful cultivation he has originated a practically permanent red clover." (*Güssow*.)

30884 and 30885.

From La Paz, Bolivia. Presented by Mr. Madden Summers, Chargé d'Affaires ad Interim, at the request of Hon. Horace G. Knowles, American Minister. Received May 12, 1911.

Seeds of the following:

30884. CITRULLUS VULGARIS Schrad. **Watermelon.**

30885. CUCUMIS MELO (L.) All. **Muskmelon.**

30886. CITRUS DECUMANA (L.) Murr. **Pomelo.**

From Yachow, China. Presented by Dr. Edgar T. Shields. Received February 23, 1911. Numbered May 15, 1911.

"Very sweet variety." (*Shields*.)

Seed.

30887 to 30889. NICOTIANA spp. **Tobacco.**

From Honduras. Presented by Dr. R. Fritzgartner, Tegucigalpa, Honduras. Received May 12, 1911.

Seeds of the following:

30887. From Piliguin, 4,000 feet altitude.

30888. From Sorognaro, 4,000 feet altitude.

30889. From Aurora, 5,000 feet altitude.

30890 and 30891.

From Diarbekr, Turkey. Presented by Mr. W. W. Masterson, American consul, Kharput, Turkey. Received May 12, 1911.

Seeds of the following:

30890. CITRULLUS VULGARIS Schrad. **Watermelon.**

"Large variety."

30891. CUCUMIS MELO L. **Muskmelon.**

"Large variety."

30892. SORBUS TORMINALIS (L.) Crantz.

From southern Russia. Presented by Mr. Theo. Kryshtofovich, Russian Government Agricultural Commissioner, St. Louis, Mo. Received May 13, 1911.

"This is a large-sized tree, the most drought resistant of the pear family, in my opinion. Its native habitat is about latitude 47° N., and longitude 37° E. It is

30892—Continued.

almost extinct. Should be tried as a stock for cultivated varieties of pears in dry localities." (*Kryshtofovich.*)

Distribution.—Throughout northern and central Europe eastward to the Caucasus region.

30893 to 30895. SOLANUM spp.

From Jamaica. Presented by Mr. William Harris, director, Public Gardens. Received May 12, 1911.

Seeds of the following:

30893. SOLANUM MAMMOSUM L.

30894. SOLANUM SEAFORTHIANUM Andrews.

30895. SOLANUM TORVUM Swartz.

30896 to 30906.

From Sukhum-Kale, Russia. Presented by Mr. R. B. Marcowitz, director, Jardin Botanique. Received May 15, 1911.

Seeds of the following:

30896. PINUS PINEA L. **Stone pine.**

Distribution.—Throughout the Mediterranean region of southern Europe, western Asia, and northern Africa.

See No. 3270 for description.

30897. CUPRESSUS FUNEBRIS Endl. **Funeral cypress.**

See No. 23024 for previous introduction.

30898. CUPRESSUS SEMPERVIRENS HORIZONTALIS (Mill.) Gord. **Cypress.**

30899. LAUROCERASUS OFFICINALIS Roem. **Cherry laurel.**

See Nos. 27360 and 27684 for previous introductions.

30900. SPARTEUM JUNCEUM L. **Spanish broom.**

See No. 27451 for previous introduction.

30901. (Undetermined.)

30902. PASSIFLORA CAERULEA L. **Passion fruit.**

Distribution.—In the provinces of Minas Geraes and Rio Grande do Sul in southern Brazil, and in Uruguay.

30903. PASSIFLORA ACERIFOLIA Hort. **Passion fruit.**

See No. 11124 for previous introduction.

30904. CORNUS AUSTRALIS C. A. Meyer.

30905. CYCLAMEN IBERICUM Steven.

Distribution.—The Trans-Caucasian region of southeastern Russia and in northwestern Persia.

30906. DIOSPYROS LOTUS L.

30907. RUBUS MACRAEI A. Gray. **Akala berry.**

From Hawaii. Presented by Dr. E. V. Wilcox, Hawaii Agricultural Experiment Station, Honolulu. Received April 17, 1911.

"The fruit attains a diameter of nearly 2 inches, is dark red, very juicy, and although slightly bitter, quite pleasant to the taste." (*Hillebrand.*)

"Would likely improve under cultivation." (*Mueller.*)

Distribution.—On the slopes of the volcanoes in the Hawaiian Islands.

30908. SONCHUS ARBOREUS (Brouss.) DC.

From Canary Islands. Presented by Dr. George V. Perez, Puerto Orotava, Teneriffe. Received May 19, 1911.

"Seed of a rare, herbaceous plant, which, like most of the Canary plants, ought to do well, I should say, in the climate of southern California, which is very much like ours. This is a very striking plant and grows over 6 feet high." (*Perez.*)

30909 and 30910.

From Moscow, Russia. Purchased from Immer & Sons. Received May 13, 1911.

Seeds of the following:

30909.	HELIANTHUS ANNUUS L.	**Sunflower.**
30910.	TRIFOLIUM PRATENSE L.	**Red clover.**

Perm.

30911. COLOCASIA sp. Taro.

From Cuba. Presented by Mr. Robt. M. Grey, director, Harvard Botanic Station, Belmonte, Cienfuegos, Cuba. Received May 15, 1911.

"Commonly cultivated here for culinary purposes." (*Grey.*)

"The tubers are slightly acrid; the flesh cooks white or yellowish white, but it is rather moist and of poor flavor." (*R. A. Young.*)

30912 and 30913.

From Porto Rico. Presented by Dr. John Gifford, Cocoanut Grove, Fla. Received at the Subtropical Plant Introduction Garden, Miami, Fla., May 8, 1911.

30912. MAGNOLIA SPLENDENS Urban. **"Laurel sabino."**

"A first-class timber tree, 50 to 100 feet in height. Olive heartwood, changing after exposure to brownish. Fine grained and aromatic. White, sweet-scented flowers, 2 to 3½ inches in diameter. Leaves with silvery pubescence underneath, although not always pubescent.

"Next to asubo (*Sideroxylon mastichodendron* Jacq.), this is probably the most valuable timber tree on the reserve. Used wherever it is not too scarce and expensive for construction work in the form of beams and boards. Valuable for cabinet work. Still found in patches in the more inaccessible parts of the reserve. Flowers, leaves, and fragrance similar to *Magnolia glauca* of the southern United States. With its light-colored trunk, silvery foliage, and fragrant, showy flowers this tree is worthy of cultivation for ornamental purposes. It is probably called 'laurel' because its leaves are used as a condiment, as is the famous laurel (*Laurus nobilis* L.) of southern Europe, and 'sabino' because of the cedary aroma of its wood." (*Gifford, J. C. The Luquillo Forest Reserve, Porto Rico. Bulletin 54, Bureau of Forestry, U. S. Department of Agriculture, 1905, p. 35.*)

Plants.

30913. THESPESIA GRANDIFLORA DC. (?) **"Maga."**

"Rare in the Luquillo region. A thick-foliaged, very beautiful ornamental shade tree with large, pendant, reddish flowers. Yields a first-class, fine, hard, olive-brown timber. Its height varies from 30 to 60 feet." (*Gifford, J. C. The Luquillo Forest Reserve, Porto Rico. Bulletin 54, Bureau of Forestry, U.S. Dept. of Agriculture, p. 36.*)

Cuttings.

30914 to 30920. CERATONIA SILIQUA L. **Carob.**

From Valencia, Spain. Received through Mr. Robert Frazer, jr., American consul, May 10, 1911.

Cuttings of the following, quoted notes by Mr. Frazer:

30914. *Matalafera.* "This is the variety now most extensively cultivated in this region and is very generally used in grafting nursery seedlings and in forming new plantations. The tree is of medium size, with smooth and straight branches, the ramifications of which are thrown out almost at right angles. The leaves are comparatively large and of a very dark-green color, and the fruit, of a deep chestnut shade bordering on black, is large and wide and attains 8 inches in length, but although of excellent appearance, is not considered as good as the red varieties, being lighter in weight and possessing less pulp. The crop of this variety, however, is the most constant and abundant of all carobs known to Valencia agriculturists."

30915. *Casuda.* "This is the most appreciated of all carobs raised in this district. The tree attains gigantic proportions, with knotty, tortuous, and abundant branches and dense foliage, the leaves being of equal size, the smaller predominating. The fruit is long, wide, and thick, of a reddish chestnut color with yellowish tints on both sides and abundant white pulp which renders it appetizing for farm cattle. The great drawback of this variety is uncertainty of crop, which frequently fails altogether or yields an insignificant harvest."

30916. Red-flowered male. "This is a much smaller and more delicate tree than the yellow flowered, very susceptible to cold, but produces a great show of flowers, which, however, frequently fall prematurely before fecundation is possible."

30917. Yellow-flowered male. "This is a vigorous tree of rapid growth which when ingrafted upon a female tree requires frequent pruning to prevent its dominating and overpowering the female branches."

30918. *Roya vera.* "This is a large tree with gnarled branches, of very irregular formation and mostly growing at acute angles; leaves light green, abundant and small. The fruit is light red in color, of medium size, 4 to 6 inches long, and produced all over the tree, trunk and branches, without clustering, seldom more than two or three pods being found united, and the pulp is white and sweet. This tree is a steady, constant, and abundant crop producer and is for this reason preferred by farmers to the other red variety (No. 30915), although the fruit is not quite so fine."

30919. "The hermaphrodite carob with bisexual flowers is something similar in appearance to the *Matalafera*, but its branches are longer, straighter, and smoother, and the smaller ramifications form acute angles with the parent branches instead of the right angles that characterize the *Matalafera*. The fruit, of a light-red color, is long and wide, growing in large clusters, but is of very inferior quality, being woody, fibrous, and tough and adheres so firmly to the trees that it can only be removed by blows with poles or cutting instruments carried by harvesters. The advantages of this tree are that it does not require grafting to fecundate its flowers and that its abundant fruit can not be swept off by high winds before maturity, as so frequently happens to other varieties. The fruit, however, is so rough and unpalatable that horses and mules accustomed to other carobs reject the hermaphrodites altogether and refuse to eat them. For this reason they are usually exported to Great Britain, France, and Italy, and are generally steeped in sea water

30914 to 30920—Continued.

30919—Continued.

before or during the voyage, a process which, by partly decomposing the woody fiber of the pods and imparting a salt flavor, is said to render them more palatable and digestible."

30920. The name of this variety was indistinct on the label, but is apparently *Roya vera*.

30921 to 30955.

From Chinese Turkestan. Received through Mr. Frank N. Meyer, agricultural explorer, May 11, 1911.

Cuttings of the following:

30921. POPULUS PRUINOSA Schrenk. **Desert poplar.**

From near Kara Kulja, Chinese Turkestan. "(No. 932, February 14, 1911.) A species of desert poplar, called *Thal Tograk*, occurring in big groves in sandy and alkali deserts mostly intermixed with *Populus euphratica*, to which it bears great resemblance in general habits. The leaves are nearly always kidney shaped, although round-oblong ones are often seen. The young twigs and leaves, however, are always tomentose. The wood is used in the same way as that of *P. euphratica*, except that as this species in general does not grow so large one can not manufacture troughs or barrels from it; it is said, however, that this wood is harder and more lasting. This poplar will be able to stand more intense heat and drought, but slightly less cold than *P. euphratica*. (*Meyer*.)

30922. POPULUS BALSAMIFERA LAURIFOLIA (Ledeb.) Wesm. **Poplar.**

From Yengi-Malah, Tien Shan Range, Chinese Turkestan. Altitude 7,950 feet. "(No. 933, March 5, 1911.) A species of wild poplar, called *Tagh terek*, growing into a small or medium-sized tree. Occurs on stony, sterile, and desolate places, mostly in the vicinity of mountain streams. Leaves somewhat leathery and varying considerably on different specimens. Bark glossy, grayish white, making a grove of these trees a very cheerful object in an otherwise dull winter landscape. Recommended as an ornamental park tree, also as a fuel supplier in cold and bleak regions. Suited especially to cool mountain climates." (*Meyer*.)

30923. SALIX sp. **Willow.**

From Yengi-Malah, Tien Shan Range, Chinese Turkestan. Altitude 7,950 feet. "(No. 934, March 5, 1911.) A willow called *Thal;* occurs along mountain streams in stony and rocky situations. Mostly seen as a tall shrub, but also grows into a small tree. Bark of young twigs yellow in color. The branches have a slight drooping habit. Apparently very resistant to cold, drought, and adverse conditions. Of value as a small garden and park tree in the cooler sections of the United States." (*Meyer*.)

30924. SALIX sp. **Willow.**

From Kailik, Tien Shan Range, Chinese Turkestan. Altitude 8,400 feet. "(No. 935, March 6, 1911.) A willow occurring on sandy and stony places. Grows into a tall shrub or small tree. Bark of old branches white, of young twigs red or yellowish red. Of value like the preceding number." (*Meyer*.)

30925. SALIX sp. **Willow.**

From near Kailik, Tien Shan Range, Chinese Turkestan. Altitude 8,200 feet. "(No. 937, March 6, 1911.) A small, shrubby willow, found on sandy flats. This willow has very long slender branches, which are remarkably

30921 to 30955—Continued.

30925—Continued.

pliable and furnish an excellent tying material. To be experimented with as a source of supply of garden-tying material and as a possible basketry willow in the cooler regions of the United States." (*Meyer.*)

30926. SALIX sp. **Willow.**

From near Kayirlik, Tien Shan Range, Chinese Turkestan. Altitude over 10,000 feet. "(No. 938, March 9, 1911.) A willow occurring on dry and stony places, grows into a good-sized, spreading bush of well-rounded shape. Suitable for use as a lining shrub along winding roads and also on flat expanses along watercourses. Will do especially well in cool mountain regions." (*Meyer.*)

30927. SALIX sp. **Willow.**

From the valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude 3,700 feet. "(No. 939, March 18, 1911.) This willow grows into a small-sized tree with a broad, round head, and looks as if it had been trimmed. The branches are of a pale greenish yellow color. Quite ornamental. Found on moist, peaty soil. Of value as a small park and garden tree in the northern sections of the United States." (*Meyer.*)

30928. SALIX sp. **Willow.**

From near Kayirlik, Tien Shan Range, Chinese Turkestan. Altitude over 10,000 feet. "(No. 941, March 9, 1911.) A willow occurring in stony débris at high altitudes. On exposed cold places it reaches only the size of a shrub, but on sheltered localities it grows into a small tree. Bark of young branches yellow in color. Of value like the preceding number." (*Meyer.*)

30929. SALIX sp. **Willow.**

From near Kayirlik, Tien Shan Range, Chinese Turkestan. Altitude over 10,000 feet. "(No. 942, March 9, 1911.) Small bushy willow, with silvery, tomentose leaves, found in rocky situations. Of value for rockery work and as a border shrub in cold, bleak regions." (*Meyer.*)

30930. TAMARIX sp. **Tamarisk.**

From near Lango, Chinese Turkestan. "(No. 943, February 13, 1911.) A tamarisk found in immense quantities on sandy and alkaline places in the desert, it is called *Kara yulrun*, and is mostly seen as a shrub 4 to 6 feet tall, but in favorable situations grows into a small tree 10 to 15 feet high. The fallen leaves and twigs intermix with the moving sand and dust, enabling this plant to build mounds often of considerable height. The old trunks in this way are buried, but new branches shoot up all the time and increase the area occupied by such mounds. The wood is an excellent fuel of great heating qualities and is extensively used. Reckless cutting and the grubbing out of roots have denuded large areas of desert lands, which formerly were covered with these tamarisk bushes and which often become moving wastes again. This tamarisk will probably be found of great value in the alkaline and desert regions of the United States as a cover plant of waste areas, as a sand binder, and as a fuel supplier. If possible, the ground water should not be too far from the surface, otherwise the plants will make very little growth." (*Meyer.*)

30931. TAMARIX sp. **Tamarisk.**

From near Tumchuk, Chinese Turkestan. "(No. 944, February 18, 1911.) A tamarisk of very spreading growth, making long, slender branches of rose-red color. Of value like the preceding number, also as an ornamental shrub in desert regions." (*Meyer.*)

30921 to 30955—Continued.

30932. Tamarix sp. **Tamarisk.**

From near Schul-Kuduk, Chinese Turkestan. "(No. 945, February 22, 1911.) A small-growing tamarisk, found in a sandy, alkali desert. Branches slender and of a pale-red color, growing 3 to 5 feet in length; these twigs are used by the native population for making strong brooms and baskets. The plants stand yearly cutting off to the ground. Of value as a broom and basketry material in the arid and semiarid regions of the United States." (*Meyer.*)

30933. Tamarix sp. **Tamarisk.**

From near Yamatu, Tien Shan Range, Chinese Turkestan. "(No. 946, March 21, 1911.) A tamarisk found on dry alkaline places at an altitude of 2,400 feet, growing into a shrub 4 to 6 feet high. Twigs of an attractive orange-brown color. Of value as an ornamental shrub in cold and dry regions." (*Meyer.*)

30934. Spiraea sp.

From Kara-Tugai, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude, 3,900 feet. "(No. 947, March 16, 1911.) A shrubby spirea, occurring on dry plains in rather heavy soils. Grows from 3 to 5 feet tall, and bears apparently white flowers. Of value possibly as a garden and park shrub in the northern sections of the United States." (*Meyer.*)

30935. Spiraea sp.

From near Schutte, Tien Shan Range, Chinese Turkestan. Altitude over 7,000 feet. "(No. 948, March 10, 1911.) A spirea found on rocky mountain sides. Has tomentose branches, and grows from 3 to 5 feet in height. Possibly of value like the preceding number." (*Meyer.*)

30936. Lonicera sp. **Honeysuckle.**

From the valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 3,700 feet. "(No. 952, March 18, 1911.) A shrubby honeysuckle, found in copses on peaty and on rocky soil. Grows 4 to 6 feet in height. The young branches are of a pale-yellow or white color and are attractive looking in winter. Of value like the preceding numbers." (*Meyer.*)

30937. Lonicera sp. **Honeysuckle.**

From near Yengi-Malah, Tien Shan Range, Chinese Turkestan. Altitude of 8,000 feet. "(No. 953, March 5, 1911.) A shrubby honeysuckle, of tall, fastigiate growth. A mutation, the only one seen among thousands of normally growing bushes. Of value as a shrub of rigid outlines along pathways, also as a background for flowering plants in cemeteries and formal gardens. To be tested with special care." (*Meyer.*)

30938. Caragana sp.

From Kurgan, Tien Shan Range, Chinese Turkestan. Altitude of 7,700 feet. "(No. 955, March 5, 1911.) A small, spiny Caragana, found on dry, stony, and sterile places. Grows from 3 to 6 feet in height, and has peculiar small adpressed side branches. A botanical curiosity. Of use as a small ornamental shrub in very dry places." (*Meyer.*)

30939. Reaumuria sp.

From near Kailik, Tien Shan Range, Chinese Turkestan. Altitude of 8,200 feet. "(No. 958, March 6, 1911.) A tall-growing shrub, adapted to sandy and rocky situations. Of slight sand-binding qualities and for this reason possibly of value for the purpose of fixing moving sandy wastes in the northern sections of the United States and as an ornamental shrub for sterile situations." (*Meyer.*)

30921 to 30955—Continued.

30940. Elaeagnus angustifolia L. **Oleaster.**

From near Yamatu, Tien Shan Range, Chinese Turkestan. Altitude of 2,500 feet. "(No. 959, March 21, 1911.) A variety of wild oleaster having a beautiful shining, chocolate-brown bark. Found on a sandy waste along the Tekes River. Grows into a tall shrub or a small tree. Of decided ornamental value for parks and gardens in the cooler sections of the United States." (*Meyer.*)

30941. Ulmus sp. **Elm.**

From Aksu, Chinese Turkestan. "(No. 962, February 25, 1911.) A cultivated variety of elm called *Seda*, forming a very dense, well-rounded head. Grows to great age and becomes through its dense black mass of branches a feature of the landscape in Turkestan. Recommended as a peculiar formal shade tree for cemeteries, also as an ornamental tree of stiff outlines in front of buildings of classical designs. A variety sent under No. 30364, which may prove to be the same as this." (*Meyer.*)

30942. Fraxinus sp. **Ash.**

From near Yamatu, Tien Shan Range, Chinese Turkestan. Altitude of 2,500 feet. "(No. 963, March 21, 1911.) An ash growing into a tall shrub or a medium-sized tree; occurs on saline, moist places. Of value possibly as an ornamental tree in the alkaline northern sections of the United States." (*Meyer.*)

30943. Ribes sp. **Currant.**

From near Idin-Kul, Tien Shan Range, Chinese Turkestan. Altitude of 8,200 feet. "(No. 964, March 10, 1911.) A wild currant, found on rocky mountain slopes in the shade of spruce trees. Of value possibly for hybridization work." (*Meyer.*)

30944. Ribes sp. **Currant.**

From near Idin-Kul, Tien Shan Range, Chinese Turkestan. Altitude of 8,200 feet. "(No. 965, March 10, 1911.) A wild currant, found on rocky mountain slopes in the shade of spruce trees. Of very tall growth, 6 to 10 feet. Young shoots covered with prickles. Possibly of value like the preceding number; also as a hardy ornamental park shrub." (*Meyer.*)

30945. Ribes sp. **Gooseberry.**

From the valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 3,700 feet. "(No. 966, March 19, 1911.) A rare species of wild gooseberry, found on shady places amidst various scrub. Young branches rather spiny. Of value possibly like preceding number." (*Meyer.*)

30946. Malus sp. **Apple.**

From Kurgan, Tien Shan Range, Chinese Turkestan. Altitude of 7,700 feet. "(No. 968, March 5, 1911.) A wild apple, which grows into a small-sized tree. Young branches very dark red in color. This form apparently stands great drought and severe cold and may be of value in hybridization work to create hardier strains of apples suitable for the coldest sections of the United States. May also be tried as a dwarfing stock in cold sections." (*Meyer.*)

30947. Malus sp. **Apple.**

From near Kitchik Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 4,100 feet. "(No. 969, March 17, 1911.) A wild apple of somewhat bushy growth, found on the northern slopes of otherwise barren mountains. Bears small round fruits of red color and subacid taste, having long peduncles. Calyx persistent. Leaves somewhat tomentose and smaller than those of

30921 to 30955—Continued.

30947—Continued.

cultivated varieties. Twigs long and strong. The bark of the main trunk and of the older branches peels off in patches and gives the tree a hardy-looking appearance. At the time of my visit (March 17) the trees were still standing in 2 feet of hard-frozen snow, and this fact, together with the decided semiarid character of the locality, the short, hot, and dry summers, and the long, cold winters, should make this species of apple a valuable one as a hybridization factor in the creation of hardier types of apples adapted to the upper Mississippi Valley region and the localities west of it." (*Meyer.*)

30948. MALUS sp. **Apple.**

From near Kitchik Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 4,100 feet. "(No. 970, March 17, 1911.) A variety of wild apple. The tree attains a height of 25 feet, has slender branches, but a good-sized trunk. Its fruits are apparently small. Seems to be much hardier than our cultivated apples. Otherwise the same remarks apply to it as to the preceding." (*Meyer.*)

30949. MALUS sp. **Apple.**

From the valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 3,700 feet. "(No. 971, March 18, 1911.) The valley of the Chong Djighilan River and its small tributaries is one vast wild apple and apricot garden, and these wild trees vary in all possible ways. The quality and size of the fruits of the wild apples exhibit great variations, ranging from small, sour, hard fruits up to medium-sized apples of a very fair taste. The local people collect the best varieties in autumn, slice them, and keep them dried for winter use; while bears and wild hogs come down from the higher mountains especially to enjoy both the apples and the apricots in late summer and autumn. These wild apples are apparently much slower growers than those we have now in cultivation, but they make up for it in all-around hardiness, and one may expect to obtain from them strains able to stand much greater cold than most of the varieties that have been developed from the apples coming originally from moist and mild western Europe." (*Meyer.*)

30950. MALUS SYLVESTRIS Miller. **Apple.**

From Aksu, Chinese Turkestan. "(No. 973, February 25, 1911.) A variety of cultivated apple called *Kabak alma*. It is said that the trees have a drooping, spreading habit and bear abundantly only every other year, also that the fruit is of oblong shape, white color, and ripens in summer. Of possible value in those sections of the United States where the summers are hot and dry, but the winters moderately cold, and where ordinary apples do not succeed." (*Meyer.*)

30951. MALUS SYLVESTRIS Miller. **Apple.**

From Aksu, Chinese Turkestan. "(No. 974, February 25, 1911.) A variety of cultivated apple called *Kizlik alma*. Said to be a very good winter apple. Shape oblong, of medium size, red on one side and greenish white on the other. Ripens in November. Of good keeping qualities and a prolific bearer. To be tested like the preceding number." (*Meyer.*)

30952. PRUNUS ARMENIACA L. **Apricot.**

From near Kitchik Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 4,100 feet. "(No. 976, March 17, 1911.) A variety of wild apricot, found between clumps of wild apples on the north side of a barren mountain, the trees standing in 2 feet of hard-frozen snow at the time of my visit. Of possible value in the creation of a race of late-blooming, hardy apricots for the northern sections of the United States." (*Meyer.*)

30921 to 30955—Continued.

30953. ASPARAGUS sp. **Asparagus.**

From Tchoa, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude of 4,300 feet. "(No. 978, March 15, 1911.) A wild asparagus of climbing habits, growing from 8 to 15 feet in length. Found between Berberis bushes. The young sprouts are eaten as a spring vegetable. Of possible value as an ornamental plant in northern regions, and as cut greens for decorative work." (*Meyer.*)

30954. MEDICAGO sp. **Alfalfa.**

From near Tuwan, Tien Shan Range, Chinese Turkestan. "(No. 979, March 14, 1911.) A wild alfalfa of erect growth, bearing yellow flowers and short flat pods. Found on clayey and peaty hill slopes at altitudes between 6,000 and 7,000 feet. Stands great cold in winter and drought in summer and is eagerly eaten by horses, cattle, and sheep. Of value, probably, as a forage plant in sections of the United States where the ordinary alfalfa is winterkilled. Native name *Yaũ beda*, in Turki, and *Serlik beda*, in Kalmuck." (*Meyer.*)

30955. MEDICAGO FALCATA L.

From the valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude of 3,700 feet. "(No. 980, March 18, 1911.) A wild alfalfa of semierect growth having yellow flowers and short, slightly curved pods; occurring on abandoned wheat fields and along the edge of cultivated lands; seems to like lime in the soil. Is considered by the local population superior in fodder value to the cultivated alfalfa. The hay of *Medicago falcata* tastes aromatically sweet, while that of *M. sativa* has a slightly saline flavor. Of value possibly as a fodder plant in elevated regions. Native names *Tagh beda*, in Turki, and *San Musu*, in Dzungan, both meaning wild or mountain lucern." (*Meyer.*)

30956 to 30962.

From Port Louis, Mauritius. Presented by Mr. Gabriel Regnard. Received May 12 and 15, 1911.

Seeds of the following:

30956. COMBRETUM COCCINEUM (Sonnerat) Lam.

Distribution.—A climbing shrub, found in Madagascar and the island of Mauritius.

30957. MIMUSOPS ELENGI L.

Distribution.—A tree attaining a height of 50 feet, common in the Dekkan, India, and the Malay Peninsula; generally cultivated in the Tropics.

30958. PITHECOLOBIUM SAMAN (Jacq.) Benth. **Saman.**

See No. 2724 for description.

Distribution.—Nicaragua and the northern part of South America.

30959. PONGAM PINNATA (L.) W. F. Wight.

See No. 27570 for previous introduction.

30960. TOLUIFERA sp.

30961. NAUCLEA ORIENTALIS L.

"A very large tree from Australia." (*Regnard.*)

Distribution.—A tree found in the Malay Peninsula and eastward through the Malay Archipelago and Polynesia to northern Australia.

30956 to 30962—Continued.

30962. Semecarpus anacardium L. f. **Marking nut.**

Distribution.—A moderate-sized deciduous tree found growing in woods from the tropical slopes of the Himalayas in Sikkim throughout the hotter parts of India and extending through the eastern islands of the Malay Archipelago to northern Australia.

30963 to 30967.

From Lamao, Philippine Islands. Received through Mr. C. V. Piper, Bureau of Plant Industry, May 17, 1911.

Seeds of the following; quoted notes by Mr. Piper:

30963. Vigna pilosa (Klein) Baker.

"A very vigorous annual (?) legume growing about as large as the Lyon bean, but producing very few pods."

30964. Pueraria phaseoloides (Roxb.) Benth.

"A common vine in forest thickets. To be tried in Mississippi and Florida."

30965 and 30966. Syntherisma ciliaris (Retz.) Schrad.

"A common species here. These two may be identical and the same as a form already in the United States. To be tried at Biloxi, Miss., and Arlington Farm, Va."

Distribution.—A form of *Syntherisma sanguinalis* (L.) Dulac found in the Tropics of the Eastern Hemisphere.

30967. Canavali sp.

"Native. Mr. Merrill considers it the wild form of *Canavali ensiforme*, a determination which I doubt. Note the pubescence on the pods. Common in thickets."

30968. Ceratonia siliqua L. **Carob.**

From Algeria. Presented by Dr. L. Trabut, Mustapha Alger, Algeria. Received May 18, 1911.

Hermaphrodite. See No. 30919 for description of similar variety.

30969. Populus tremula L. **Aspen.**

From St. Petersburg, Russia. Presented by Mr. W. W. Rockhill, American ambassador. Received May 19, 1911.

See No. 29098 for description.

30970. Garcinia dulcis (Roxb.) Kurz.

From Singapore, Straits Settlements. Presented by Dr. H. N. Ridley, director, Botanic Gardens. Received May 19, 1911.

Introduced for testing as a stock for the mangosteen, which has a notably poor root system.

Distribution.—A medium-sized tree found in the islands of the Malay Archipelago.

30971 and 30972. Mangifera indica L. **Mango.**

From San Jose, Costa Rica. Presented by Mr. C. Wercklé, Museo Nacional. Received May 15, 1911.

Cuttings of the following:

30971. *Rosa.* **30972.** *Scarlet.*

30973. VITIS VINIFERA L. **Grape.**

From Tiflis, Caucasus, Russia. Presented by Mr. A. Rolloff, Botanical Garden. Received May 19, 1911.

"*Schaani.*"

30974. LUPINUS sp. **Blue lupine.**

From the eastern slope of Chiriqui Volcano, Panama, about 9,970 feet altitude. Collected by Mr. Wm. R. Maxon, assistant curator, Division of Plants, Smithsonian Institution. Received May 23, 1911.

"I do not know that this species is of any particular value." (*Maxon.*)

30975 to 31093.

From St. Petersburg, Russia. Presented by the director, Imperial Botanic Garden. Received May 20, 1911.

Seeds of the following:

30975. AMYGDALUS BUCHARICA Korsh.

Distribution.—On the slopes of the mountains in the province of Bokhara in southern Turkestan.

30976. ASPARAGUS OFFICINALIS L. **Asparagus.**

30977. BETA PATELLARIS Moq.

Distribution.—A biennial plant growing in the sand on the shores of the Canary Islands.

30978. BETA VULGARIS L. **Beet.**

30979. BETULA sp. **Birch.**

30980. COTONEASTER TOMENTOSA (Ait.) Lindl.

See No. 28213 for previous introduction.

30981. CRATAEGUS CRENULATA Roxb. **Hawthorn.**

See No. 28845 for previous introduction.

30982. PHOTINIA GLABRA (Thunb.) Maxim.

Distribution.—A shrub found in the vicinity of Yokohama in Japan, and near Ningpo in the province of Chekiang, and Amoy in Fukien, China.

30983. EUONYMUS NANUS Bieb.

A handsome shrub for rockeries and rocky slopes.

Distribution.—Southern Asia, extending from the Caucasus region eastward through Turkestan and Mongolia to the provinces of Kansu and Shensi in China.

30984. IRIS HALOPHILA Pallas. **Iris.**

30985. IRIS SPURIA NOTHA (Bieb.) Baker. **Iris.**

Distribution.—From the Caucasus region eastward to Kashmir in India.

30986. KNAUTIA ARVENSIS (L.) Coulter.

Distribution.—Throughout Europe, especially in the northern and central parts, and eastward to the Ural Mountains in Siberia.

30987. LALLEMANTIA IBERICA (Bieb.) Fisch. and Meyer.

See No. 29932 for previous introduction.

30988. LONICERA CAERULEA L. **Honeysuckle.**

Distribution.—A much-branched shrub found in Europe and Asia, extending southward to the Alps and the Pyrenees, and eastward to Japan.

30975 to 31093—Continued.

30989. Lonicera hispida Pallas. **Honeysuckle.**

Distribution.—An erect shrub found in central Asia on the slopes of the Himalayas and the Altai Mountains at an elevation of 9,000 to 15,000 feet.

30990. Lonicera morrowi A. Gray. **Honeysuckle.**

Distribution.—On the slopes of the mountains in the island of Hokushu (Yezo), Japan.

30991. Mertensia sibirica (L.) Don.

Distribution.—Northeastern Siberia, extending from the valley of the Lena River eastward to Kamchatka.

30992. Medicago hispida aculeata Urban.

Distribution.—Southern France and Spain, and in northern Africa.

30993. Circinnus circinatus nummularius (DC.) Skeels.

(*Medicago nummularia* DC., Catalogus Plantarum Horti Botanici Monspeliensis, 1813, p. 124.)

This Egyptian leguminous plant was first given a specific name, *Medicago nummularia*, by De Candolle, who, in describing it, cited Gaertner's figure of *Medicago circinata* (De Fructibus et Seminibus Plantarum, 1791, vol. 2, p. 348, pl. 155) and Willdenow's *M. circinata β.* (Species Plantarum, 1801, vol. 3, p. 1404.) *Medicago circinata* L. has a reniform pod with a dentate margin. In *M. nummularia* Willd., the margin of the pod is entire. These plants are generally known as *Hymenocarpos circinatus* and *H. nummularius*. The generic name Hymenocarpos was published by Savi in 1798 (Flora Pisana, vol. 2, p. 205), with one species, *H. circinata*, based on *Medicago circinata* L. However, in 1787 Medicus had already published the generic name Circinnus (Vorlesungen der Kurpfaelzischen Physikalisch-Oekonomischen Gesellschaft, vol. 2, p. 384), also based on *Medicago circinata* L. While this book is not obtainable, the publication is verified by the Index Kewensis, and Medicus again published the name in 1789 in Philosophische Botanik, vol. 1, p. 208, where he referred to the former publication and again cited *Medicago circinata* L. Not considering our form to be distinct enough to be given specific rank, it is here placed under *Circinnus circinatus* as a subspecies.

Circinnus circinatus nummularius was first found in cultivated fields in Egypt and is also known to grow in the southern part of Persia.

30994. Medicago rigidula (L.) Desr.

30995. Medicago hispida confinis (Koch) Burnat.

30996. Medicago hispida reticulata (Benth.) Urban.

Distribution.—Southern France, Spain, and Portugal in southwestern Europe, and in northern Africa.

30997. Medicago scutellata (L.) Miller.

30998. Medicago hispida apiculata (Willd.) Urban.

Distribution.—The western part of Europe, extending from the British Isles southward through France to Spain and Italy, and in northern Africa.

30999. Medicago laciniata (L.) Miller.

Distribution.—The countries bordering on the Mediterranean from Spain and southern France eastward through Italy and Asia Minor to Persia, and in northern Africa and the Canary Islands.

31000. Medicago sativa L. **Alfalfa.**

30975 to 31093—Continued.

31001. Medicago rigidula cinerascens (Jord.) R. and F.

Distribution.—The countries bordering on the Mediterranean from Spain to Syria, and in northern Africa.

31002. Medicago hispida apiculata (Willd.) Urban.

31003. Medicago hispida terebellum (Willd.) Urban.

31004. Medicago minima (L.) Grufb.

31005. Medicago falcata L.

31006. Medicago murex sorrentini (Tin.) Urban.

Distribution.—In the island of Sicily and in Italy.

31007. Medicago soleirolii Duby.

Distribution.—In the island of Corsica and in northern Africa.

31008. Trigonella arcuata Meyer.

Distribution.—In dry places in Armenia and in northern Persia.

31009. Medicago prostrata Jacq.

Distribution.—Southern Europe, extending from Italy and Sicily eastward through the Balkan Peninsula to the southwestern part of Russia.

31010. Medicago hispida Gaertn.

31011. Medicago hispida reticulata (Benth.) Urban.

31012. Medicago hispida terebellum (Willd.) Urban.

31013 and 31014. Medicago lupulina L.

31015. Medicago hispida apiculata (Willd.) Urban.

31016. Medicago obscura helix (Willd.) Urban.

Distribution.—The countries at the western end of the Mediterranean, extending from Spain and Italy through the islands and northern Africa.

31017. Medicago hispida Gaertn.

31018. Medicago hispida aculeata Urban.

31019. Medicago ciliaris (L.) All.

31020. Trigonella ovalis Boiss.

31021. Medicago echinus DC.

Distribution.—In fields and cultivated places in the provinces of France bordering on the Mediterranean.

31022. Medicago hispida confinis (Koch.) Burnat.

31023. Medicago hispida terebellum (Willd.) Urban.

31024. Medicago hispida aculeata Urban.

31025. Meconopsis simplicifolia (Don) Hook. f. and Thomson.

Introduced with others of the genus for trial in the hope of finding a thoroughly hardy blue poppy and also for possible use in breeding work with the hardier poppies already in cultivation.

Distribution.—A perennial herb with large blue-purple flowers, found on the subalpine slopes of the Himalayas at an elevation of 12,000 to 14,000 feet, in Nepal and Sikkim in northern India.

31026. Primula denticulata Smith. **Primrose.**

A hardy plant usually treated as a rockwork subject. Blooms in earliest spring.

30975 to 31093—Continued.

31026—Continued.

Distribution.—In damp places on slopes of the Himalayas at an altitude of 7,000 to 13,000 feet, from Bhutan to Kashmir, and at an altitude of 5,000 feet in the Khasi Hills, India; also in Afghanistan.

31027. HYPERICUM PATULUM Thunb.

See No. 1710 for previous introduction.

Distribution.—Southeastern Asia, extending from the Himalayan region of northern India eastward through China to central and southern Japan.

31028 to 31032. MALUS BACCATA (L.) Moench.

- **31028.** Variety *microcarpa.*
- **31029.** Variety *costata.*
- **31030.** Variety *edulis.*
- **31031.** Variety *aurantiaca.*
- **31032.**

31033. SORBUS ARIA (L.) Crantz.

Variety *latifolia.*

31034. ROSA FERRUGINEA Villars. **Rose.**

See No. 30263 for previous introduction.

31035. RHEUM PALMATUM TANGUTICUM Maxim. **Rhubarb.**

See No. 21761 for previous introduction.

31036. RHEUM SPICIFORME Royle. **Rhubarb.**

Distribution.—On the dry slopes of the Himalayas, at an altitude of 9,000 to 16,000 feet, from Afghanistan to Tibet.

31037. RHEUM AUSTRALE Don. **Rhubarb.**

See No. 21763 for previous introduction.

31038. RHEUM PALMATUM L. **Rhubarb.**

Variety *corallinum.*

31039. RHEUM PALMATUM L. **Rhubarb.**

Red-flowered variety.

31040. RHEUM RHAPONTICUM L. **Rhubarb.**

See No. 21758 and 21760 for previous introduction.

31041. RHEUM FRANZENBACHII Muenter.

Distribution.—In the mountain valleys of the province of Shensi, China.

31042. RHEUM MOORCROFTIANUM Royle. **Rhubarb.**

See No. 21766 for previous introduction.

31043. TRIFOLIUM SCABRUM L. **Clover.**

31044. TRIFOLIUM CHERLERI Jusl. **Clover.**

Distribution.—The countries bordering on the Mediterranean from Spain to Syria, and in northern Africa.

31045. TRIFOLIUM PANNONICUM Jacq. **Hungarian clover.**

31046. TRIFOLIUM MEDIUM Huds. **Zigzag clover.**

31047. TRIFOLIUM SPUMOSUM L. **Clover.**

31048 and 31049. TRIFOLIUM AGRARIUM L. **Golden clover.**

31050. TRIFOLIUM CERNUUM Brot. **Clover.**

Distribution.—In the vicinity of Cintra in Portugal, and Spain.

30975 to 31093—Continued.

31051. Trifolium striatum L. **Clover.**

Distribution.—Western and southern Europe, extending from Norway and Sweden southward to Spain and eastward to Asia Minor and the Caucasus region, and in northern Africa.

31052. Trifolium incarnatum L. **Crimson clover.**

31053. Trifolium reclinatum Waldst. and Kit.

Distribution.—In grassy places in Hungary, Servia, and Macedonia.

31054. Trifolium tumens Stev. **Clover.**

Distribution.—In grassy fields on the slopes of the mountains in the Trans-Caucasian region of Russia and in northern Persia.

31055. Trifolium alexandrinum L. **Berseem.**

31056. Trifolium pratense L. **Red clover.**

31057. Trifolium lappaceum L. **Clover.**

31058. Trigonella foenum-graecum L. **Fenugreek.**

31059. Trigonella procumbens (Bess.) Reichenb.

Distribution.—Southeastern Europe, extending from the Balkans eastward through southern Russia and the Caucasus region to Asia Minor.

31060. Trigonella corniculata L.

31061. Trigonella cretica Boiss.

31062. Trigonella polycerata L.

31063. Trigonella polycerata L.

Variety *dentata*.

31064. Trigonella caerulea (L.) Ser.

Variety *connata*.

31065. Trigonella calliceras Fisch.

31066. Trigonella gladiata Stev.

31067. Trigonella spinosa L.

Distribution.—In grassy places in the island of Crete, and along the shores of the southern part of Asia Minor and Syria and Palestine.

31068. Trigonellea caerulea (L.) Ser.

31069. Medicago radiata L.

31070. Tilia rubra beg0nifolia (Stev.) Schneider.

Distribution.—In the Crimean Peninsula and the Caucasus region of southeastern Russia, Armenia, and northern Persia.

31071. Agropyron sibiricum (Willd.) Beauv.

31072. Trollius ledebourii Reichenb.

Distribution.—A hardy, herbaceous perennial found on the margins of woods or in damp open fields near streams throughout Manchuria.

31073. Vicia sativa L. **Spring vetch.**

31074. Vicia villosa Roth. **Hairy vetch.**

31075. Vicia sativa leucosperma (Moench) Ser.

31076. Vicia pseudocracca Bertol.

31077. Vicia cornigera Chaub.

Distribution.—A form apparently closely related to *Vicia sativa*, found in the vicinity of Agen, France.

30975 to 31093—Continued.

31078. VICIA HIRSUTA (L.) S. F. Gray.

31079. VICIA MELANOPS Sibth. and Smith.

Distribution.—The central and southern part of Italy, the islands of Sicily, and eastward to Greece.

31080. VICIA PICTA Fisch. and Meyer.

Distribution.—In copses from Dalmatia eastward through southern Russia to Siberia.

31081. VICIA SATIVA L. **Spring vetch.**

31082. VICIA SATIVA OBOVATA Ser.

31083. VICIA ANGUSTIFOLIA Grufberg.

31084. VICIA SATIVA LEUCOSPERMA (Moench) Ser.

31085. VICIA SYLVATICA L.

Distribution.—Western and southern Europe, extending from Norway, Sweden, and the British Isles southward to southern France, Italy, Corsica, and Sardinia, and eastward through Servia and Roumania to southern Russia.

31086 to **31088.** VICIA spp.

31089. VICIA ONOBRYCHIOIDES L.

Distribution.—Southern France, Spain, and eastward through Italy to Greece; also in northern Africa.

31090. VICIA ANGUSTIFOLIA Grufberg.

31091. VICIA DISPERMA DC.

31092. VICIA MICHAUXII Spreng.

Distribution.—Along cultivated fields in Mesopotamia, Syria, and southern Persia.

31093. VICIA DUMETORUM L.

Distribution.—Western and southern Europe, extending from Norway and Sweden southward to Spain and eastward through Italy, Bulgaria, and Greece to southern Russia and southwestern Siberia.

31094. CASTANEA CRENATA Sieb. and Zucc. **Chestnut.**

From Japan. Presented by the Agricultural College, Tohoku Imperial University, Sapporo, Japan. Received May 25, 1911.

This is probably the *Aomori* variety, which is one of the hardier Japanese varieties, introduced for the work of a breeder who is trying to produce disease-resistant strains of chestnut.

31095 and 31096.

From Baguio, province of Benguet, Philippine Islands. Received through Mr. C. V. Piper, Bureau of Plant Industry, May 25, 1911.

Seeds of the following; quoted notes by Mr. Piper:

31095. ROSA MULTIFLORA Thunb. **Rose.**

"An evergreen (?) species with stems 3 to 10 feet high. Flowers white, small, in cymes of 10 to 15. Suggests the Cherokee rose on a small scale."

31096. RUBUS FRAXINIFOLIUS Poir.

"Shrub 5 to 10 feet high, quite erect, stems not very prickly, red; leaves evergreen, shiny, pinnate, with 7 leaflets; fruit scarlet, as large as a big raspberry, with very numerous small drupelets; not much flavor."

31095 and 31096—Continued.

31096—Continued.

Distribution.—Apparently one of several forms closely related to *Rubus rosaefolius* Smith, and found from India eastward through the Malay Archipelago to Australia.

31097. JUBAEA CHILENSIS (Mol.) Baill. **Palm.**

From Chile. Received through Mr. José D. Husbands, Limavida, via Molina, Chile, May 26, 1911.

"The tree is called *Palma de Chile;* the fruit *Coquitos;* Indian names *Lilla* and *Caucau*. This is the tall, slim sort with a trunk about 18 or 20 inches in diameter. Practically all these trees are found at the hacienda 'Palmas de Ocoa,' where there are said to be over 2,500, forming woods upon the dry, level land; in other parts of Chile they are very scarce, only individual trees are found rarely and at great distances apart. They do not grow in the south, I presume on account of the moisture. They grow in the driest parts. In the hacienda 'Palmas de Ocoa,' they manufacture palm sirup upon a large scale. It is very good and healthful and is in general use among well-to-do families. It is too high to be used by the poor, as a small can 2¾ inches in diameter by 4½ inches high costs 50 cents gold. This is also served alone as a dessert dish.

"I fear these magnificent trees, tropical plants that withstand hard frosts and the greatest droughts, will become extinct in the near future, for they are tapped, generally with an ax, each year; no proper attention is paid to conservation." (*Husbands.*)

31098. ERYTHRINA LITHOSPERMA Blume.

From Mandalay, Burma. Presented by Mr. J. Mackenna, Director of Agriculture. Received May 19, 1911.

"This is known in Burmese as *Ye-ka-thit.*" (*Mackenna.*)

Procured for the Porto Rico Agricultural Experiment Station for experimental growing as a shade in young coffee and cacao plantations.

Distribution.—In the vicinity of Rangoon in southern Burma and in Java and the Philippine Islands.

31099. ORYZA SATIVA L. **Rice.**

From Soochow, China. Presented by Mr. N. Gist Gee, Department of Natural Science, Soochow University. Received May 27, 1911.

"This is a peculiar variety of rice which the Chinese grow near here that is not grown elsewhere, they say. This rice when cooked shows a very decidedly reddish color, and for this reason it is called *Shuih no me* in our dialect; this translated means blood glutinous rice. The general belief among them is that it is a rapid strength giver, and they all make an effort to get some of it when they have been sick or run down physically for some time. I am not ready to vouch for any of their beliefs about it except its peculiar color. I have eaten it and find its color when cooked quite unusual." (*Gee.*)

31101. LUPINUS sp.

From Paraguay. Presented by Dr. Moises S. Bertoni, Puerto Bertoni, Paraguay. Received May 26, 1911.

"This is a wild species that grows in the most sterile soils, even in the loose sand of the river shore." (*Bertoni.*)

31102. LALLEMANTIA IBERICA (Bieb.) Fisch. and Mey.

From Erfurt, Germany. Purchased from Haage & Schmidt. Received May 26, 1911.

See No. 29932 for description.

31103. CHRYSANTHEMUM COCCINEUM Willd.

From Ungarisch-Altenburg (Magyar-Ovar), Hungary. Presented by Mr. J. Gyárfás, chief, Hungarian Plant-Culture Experiment Station. Received May 29, 1911.

Distribution.—Alpine and subalpine slopes of the mountains in the Caucasus region of southeastern Russia, Armenia, and northern Persia.

Introduced for the work of the Office of Drug-Plant, Poisonous-Plant, and Physiological Investigations in growing in the United States the various species of this genus which produce the pyrethrum insect powder.

31104. PHOENIX DACTYLIFERA L. Date.

From Tangier, Morocco. Presented by Mr. W. B. Harris. Received through Mr. Maxwell Blake, American consul general, June 1, 1911.

Tafilelt. See No. 18630 for description.

Seeds.

31105 to 31108.

From Nanking, China. Presented by Mr. F. B. Whitmore. Received May 29, 1911.

Seeds of the following:

31105 and 31106. HORDEUM VULGARE var. **Barley.**

31105. **31106.** Hull-less.

"The Chinese say one of their sages, about 600 B. C., found barley growing wild in what is now Chinese Turkestan, brought it to his people, and advised its use. The northern variety makes better flour, whiter, the Chinese say, because it blossoms at night, so men can live on it continually, while they can not live only on that grown in the South; it is too strong, because it blossoms in daytime." (*Whitmore.*)

31107. TRITICUM AESTIVUM L. **Wheat.**

31108. FAGOPYRUM VULGARE Hill. **Buckwheat.**

31109 and 31110. CARICA PAPAYA L. Papaya.

From Port of Spain, Trinidad. Presented by Mr. H. Caracciolo, St. Joseph's Nursery. Received May 22, 1911.

Seeds of the following:

31109. "The specimen from which these seeds were taken was oval, 9 by 6½ inches, and weighed 5½ pounds. The flesh was about 1 inch thick. The fruit arrived in very poor condition, which made it impracticable to say positively as to its quality; however, even under these conditions it possibly could be classed as very good." (*P. H. Dorsett.*)

31110. "The fruit from which these seeds were taken was 10 inches long by 5 inches in diameter at the large end and 3 inches at the small end. On account of the poor condition in which it arrived the quality could not be definitely determined, but it could probably be called very good." (*P. H. Dorsett.*)

31111. CARISSA OVATA R. Brown.

From New South Wales. Presented by Mr. Walter Froggatt, who procured them from Mr. R. T. Baker, curator, Technological Museum. Received May 27, 1911.

This native Australian species, the fruit of which is edible and largely used for jam, is introduced for use as a stock for the tenderer species of the genus in the hope of spreading the culture of this important home-garden fruit.

Distribution.—In the provinces of Queensland and New South Wales in Australia.

31112. HORDEUM VULGARE var. **Hull-less barley.**

From Sydney, New South Wales, Australia. Presented by Mr. Geo. Valder, chief inspector, through Mr. H. C. L. Anderson, undersecretary, Department of Agriculture. Received June 1, 1911.

31114. GOSSYPIUM sp. **Kidney cotton.**

From San Pedro Macati, near Manila, Philippine Islands. Presented by Dr. E. D. Merrill, Bureau of Science. Received May 26, 1911.

"This is a shrub 2 to 2½ meters (6½ to 8 ft.) high, commonly cultivated in the Philippines, but scarcely commercially; usually known as *bulac castila*, meaning 'Spanish cotton." (*Merrill.*)

31115. PHYTELEPHAS SEEMANNI O. F. Cook n. sp.

Panama ivory palm.

"As already recognized by Spruce as far back as 1869, the name *Phytelephas macrocarpa* does not belong to the vegetable-ivory palm described by Seemann from Panama (Botany of the *Herald*, 1852–1857, pls. 45–47, p. 205). Two species, *macrocarpa* and *microcarpa*, both from the eastern slopes of the Andes of Peru, were named by Ruiz and Pavon in connection with the original description of the genus Phytelephas, but without distinctive characters other than the size of the fruits. Seemann did not know the Peruvian species, but was aware that the Panama palm was different from another Phytelephas found by Purdie in the upper valley of the Magdalena River in Colombia, supposed by Karsten to represent *Phytelephas microcarpa*. Spruce's account of the true *macrocarpa* of Peru leaves no doubt that the Panama species is entirely distinct. It has the trunk decumbent and creeping instead of upright, the leaves with fewer, larger pinnae, the spathes two instead of three or four, the male flowers with 36 stamens instead of 150 to 280. The fruits also are larger and contain more numerous nuts, but with fewer fruits in a head." (*O. F. Cook.*)

From Panama Canal Zone. Presented by Mr. Pablo Pinel, Panama. Received June 1, 1911.

31116 to 31192. ORYZA SATIVA L. **Rice.**

From Philippine Islands. Presented by Mr. Sam H. Sherard, agricultural inspector, Bureau of Agriculture, Manila. Received April 18, 1911.

Seeds of the following; quoted notes and names by Mr. Sherard:

"A complete list of all rice (palay) collected in January, Iloilo. This rice is classified in the following manner: *Bohol*, white and colored; hard when cooked. *Bisia*, white; soft when cooked. *Pilit*, colored; sticky when cooked. These kinds are further classified as *Munahan*, harvested in July and August; *Dagunan*, harvested in September, October, and November; *Ma-ean*, harvested in December and January."

31116 to 31192—Continued.

31116 to 31157. *Bisia.*

31116 to 31130. *Munahan.*

31116. *Biray.*
31117. *Benihod.*
31118. *Bugna.*
31119. *Cahon-bon.*
31120. *Cabu-ong.*
31121. *Cadimayan.*
31122. *Calotac.*
31123. *Caporcas.*
31124. *Casicad.*
31125. *Magsana-ya.*
31126. *Ontramis.*
31127. *Quinopong.*
31128. *Rimocon.*
31129. *Tinabono.*
31130. *Tinoramis.*

31131 to 31153. *Dagunan.*

31131. *Cabilistos.*
31132. *Cabuad.*
31133. *Cadacag.*
31134. *Calaya.*
31135. *Calipayan.*
31136. *Capurcos.*
31137. *Caracag.*
31138. *Catoc-toc.*
31139. *Caton-og.*
31140. *Catorsa.*
31141. *Catunda.*
31142. *Ceredonce.*
31143. *Dinalosan.*
31144. *Manumbalay.*
31145. *Quinaluay.*
31146. *Tayabas.*
31147. *Ylognon.*
31148. *Maguenos.*
31149. *Caouay.*
31150. *Tabucanan.*
31151. *Pinili.*
31152. *Lonag.*
31153. *Diamante.*

31154 to 31157. *Ma-can.*

31154. *Calubug.*
31155. *Saigon.*
31156. *Siniflora.*
31157. *Bulacnaga.*

31158 to 31166. *Bilit.*

31158 and 31159. *Munahan.*

31158. *Munahan.*
31159. *Minantica.*

31160 to 31163. *Dagunan.*

31160. *Dayoyo.*
31161. *Morado.*
31162. *Soladang.*
31163. *Quinarne.*

31164 to 31166. *Ma-can.*

31164. *Jumiad.*
31165. *Moranquit.*
31166. *Quinarabao.*

31167 to 31186. *Bohol.*

31167 to 31169. *Munahan.*

31167. *Cutchiam.*
31168. *Guinatus.*
31169. *Marong-paroc.*

31170 to 31178. *Dagunan.*

31170. *Barao.*
31171. *Caleso.*
31172. *Capungod.*
31173. *Caputol.*
31174. *Delinquente.*
31175. *Pinili.*
31176. *Quinadios.*
31177. *Tumanan.*
31178. *Camarines.*

31116 to 31192—Continued.

31167 to 31186—Continued.

31179 to 31186. *Ma-can.*

31179. *Arabuon.*

31180. *Cabonlog.*

31181. *Quilala.*

31182. *Morado.*

31183. *Tapul.*

31184. *Carnate.*

31185. *Pinili.*

31186. *Calana.*

31187 to 31190. Raised in Munoz, Nueva Ecija, by Mr. Percy Hill.

31187. *Malakit*, or sticky palay. Planted July 5, transplanted September 2, harvested December 22, 1910.

31188. *Palay lloco.* Planted June 12, transplanted July 28, harvested December 18, 1910.

31189. *Paaga-Binuncloc*, or early palay. Planted broadcast June 20, harvested October 25, 1910. Yielded 48.3 bushels per acre.

31190. *Minalit.* Planted June 30, transplanted August 19, harvested January 2. Average yield 73.2 bushels per acre. A good eating rice.

31191. *Dampites.* From province of La Union.

31192. *Ilocano.* From province of Nueva Ecija.

31193. CASTILLA sp. **Central American rubber.**

From Mexico. Presented by Mr. J. C. Harvey, Plantación La Buena Ventura, Sanborn, Vera Cruz, Mexico. Received June 5, 1911.

Introduced for the work of the Bureau in encouraging rubber culture in Porto Rico, the Canal Zone, and Hawaii.

31194. SPHENOSTYLIS STENOCARPA (Hochst.) Harms.

From Amani, German East Africa. Presented by Dr. A. Zimmerman, director, Biological Agricultural Institute. Received June 5, 1911.

"This is a legume which forms edible tubers, and which is cultivated by the natives in the region of Tabora. The taste of the tubers is similar to potatoes." (*Zimmerman.*)

Distribution.—From the valley of the Kongo southward to Angola on the west coast of Africa and on the east coast from Abyssinia southward to Mozambique.

31195. LINUM sp. **Wild linseed.**

From Szechwan, China. Presented by Mr. A. Sugden, Custom House, Hankow. Received June 5, 1911.

"This seed is sown in June in sandy soil and untended, the Chinese saying it refuses to be cultivated." (*Sugden.*)

31197. ENTELEA ARBORESCENS R. Br. **Whau.**

From Wellington, New Zealand. Presented by Mr. T. W. Kirk, Director of Orchards, Gardens, and Apiaries, Department of Agriculture, Commerce, and Tourists. Received June 5, 1911.

See No. 11746 for previous introduction.

31198 to 31202. ULLUCUS TUBEROSUS Caldas. **Melloca.**

From the province of Jauja, department of Junin, Peru. Presented by Mr. James Arthur Furlong, Perene Colony, Peru. Received June 5, 1911.

Tubers of the following:

31198. Orange.

31199. Orange red.

31198 to 31202—Continued.

31200. Yellow.

31201. Mottled red.

31202. Cream colored, spotted with red.

"These tubers grew at an elevation of about 12,000 feet, in poor and stony soil, worked with wooden plows. The Ullucus are sown in drills like potatoes, after which they are molded and worked with hoes." (*Furlong.*)

"The melloca is half a runner; its shoots, without support, send out roots wherever the ground is touched. Its leaves are thick and fleshy; from being large and spreading, they become erect and round like a shell in the fully developed plant. The flowers, which are small and greenish, spring in spikes from the axil of the leaves. The produce of the melloca consists in its tubers, which in their native country attain a considerable size. They are yellow, very smooth, full of starch, and appear on runners proceeding from the base of the stem and tending to rise to the surface of the soil; the plant must, therefore, be pretty well earthed up." (*Vilmorin, Jour. Hort. Soc. of London, vol. 5, 1850, p. 65.*)

"I have found this in all the Andean valleys between the River Apurimac and Potosi, i. e., between 13° and 19° 30′ south latitude, and at an elevation of from 11,000 to 13,000 feet above the level of the sea. It is extensively cultivated in the vicinity of the populous Bolivian city of La Paz in common with the two varieties of *Oxalis tuberosa* (*Oca augris* and *Oca esaños*). It (the *Oca quina*) is planted between the 25th of July and the 10th of August, the seed employed being generally the smaller tubers unfit for food, and is gathered in during the last week of April. It will be recollected that these two periods of the year are the spring and autumn in the Southern Hemisphere. The mode of cultivation is in drills, into which the root is dropped with a little manure. I need scarcely state that at the great elevation of La Paz (upward of 12,000 feet) the climate even during the summer season is severe, scarcely a night passing over without the streams being frozen over, the sky being in general cloudless at all periods of the year except during the rainy season (December to March). Mean temperature 49°. The *Oca quina* (or melloca) is chiefly used in the preparation of Chuño, by alternately freezing the tubers and steeping, by which they are changed into an amylaceous substance, the form under which not only the Ocas but the common potato are chiefly employed by the Indian population; an operation probably introduced from the difficulty of boiling the unprepared tuber at an elevation above the sea where the point of ebullition of water is scarcely high enough to cook raw vegetables, 192° to 195° of Fahrenheit's scale." (*Pentland, J. B. Gardeners' Chronicle, No. 53, 1848, p. 862.*)

"In addition to these statements I think it right to say that there is little probability of this plant becoming useful as a garden esculent. Its produce will probably be found large when it is cultivated in the manner which the experience already gained shows to be necessary to it, namely, when planted in the beginning of March, the little tubers being used for sets, earthed up in July, and harvested in November. The leaves and tubers are no doubt nutritive but so full of an insipid and somewhat earthy slime that whether as spinach or as boiled tubers it will never be received at the table of persons of taste." (*Lindley, Jour. Hort. Soc. of London, vol. 5, 1850, p. 69.*)

31203. CLAUCENA LANSIUM (Lour.) Skeels. **Wampee.**

From Edinburgh, Scotland. Presented by the Regius Keeper, Royal Botanic Garden. Received June 1, 1911.

See Nos. 25546 and 27954 for previous introductions.

31204. Caryocar villosum (Aubl.) Persoon. **Piquiá.**

From Para, Brazil. Presented by Mr. Walter Fischer, acting director, Campo de Cultura Experimental Paraense. Received May 26, 1911.

"The piquiá is one of the forest trees of this vicinity that is highly prized for its lumber. The wood is extremely hard and strong, so strong in fact that the word piquiá is almost symbolic for strength; it is white and close grained. I have seen but one tree that stood in the open; in fruit with nearly all of its leaves shed it resembled one of our black walnuts in the fall of the year. The fruit is boiled before eating. After peeling off the thick rind, there remains a fatty layer of one-half inch thickness inclosing a rather spiny seed as large as a walnut in the hull. It is this fatty layer which is eaten boiled, but the kernel of the seed is eaten raw." (*Fischer.*)

Distribution.—A large tree in the forests of the northern part of South America, extending from Guiana southward to the valley of the Amazon in Brazil.

31206. Musa sp. **Banana.**

From Paraguay. Presented by Mr. C. F. Mead, Villa Encarnacion. Received June 6, 1911.

"This sucker came from an especially fine banana plant, one from which I cut a bunch weighing 52 kilos (114.64 lbs.). The bunch of bananas cost me 24 cents gold. This fruit was pronounced by four Argentinians as the finest flavored banana they had ever eaten." (*Mead.*)

31207. Passiflora sp. **Passion fruit.**

From Montevideo, Uruguay. Presented by Mr. Frederick W. Goding, American consul. Received June 6, 1911.

"This fruit, indigenous to Uruguay, is called the *Viricuya.* It is a long, climbing, perennial vine, which is found only in forests along the margins of streams. The fruit, which is ripe here about the first of April, is similar in size and shape to a lemon. The skin is of a lovely orange yellow, smooth and shining. The interior is filled with a most luscious siruplike juice with a flavor peculiar to itself but most satisfactory to the taste. It contains a large number of seeds, resembling those found in the passion fruit.

"No seeds are on sale in the seed stores at present, and as the vine grows wild in unfrequented parts of the republic considerable difficulty will be experienced in obtaining a supply." (*Goding.*)

31208 and 31209. Triticum spp. **Wheat.**

From Khartum, Egypt. Presented by Mr. R. Hewison, Assistant Director of Agriculture, Sudan Government. Received June 7, 1911.

Seeds of the following; quoted notes by Mr. Hewison:

31208. *Dongola.* "This wheat is the sort grown by the native cultivators in the Dongola Province, but I am unable to discover its origin."

31209. *Indian.* "This was received from Egypt, where it had been grown. The crop from which this sample was taken is the third grown in the Sudan from the imported seed."

"These two wheats are from the crop that is now being harvested and have been grown on a commercial scale. They have both been grown under irrigation, were sown in November and harvested in March, actual period of growth being about four months. The seed is broadcast on land that has been watered about eight days previously and plowed in with the Egyptian plow. Five to six waterings are given subsequently and our average yield for some 50 acres will this year amount to about 22 bushels per acre.

31210 to 31223.

From Lahore, India. Presented by Mr. W. R. Mustoe, superintendent, Government Agri-Horticultural Gardens. Received June 6, 1911.

Seeds of the following:

31210 to 31214. Procured from fruits purchased on the open market at the request of Mr. F. Booth Tucker, Salvation Army, Simla, India.

31210. CITRUS LIMONUM Risso. **Lemon.**

31211 and 31212. CITRUS LIMETTA Risso. **Lime.**

31211. *Kaghzi.* **31212.** Sour.

31213. CITRUS DECUMANA (L.) Murr. **Pomelo.**

Chakatra.

31214. CITRUS AURANTIUM SINENSIS L. **Orange.**

Nagpore.

31215 to 31223. Collected from fruit grown in the gardens.

31215. CITRUS LIMONUM Risso. **Lemon.**

Malta.

31216 and 31217. CITRUS LIMETTA Risso. **Lime.**

31216. *Khatta*, sour. **31217.** Large sweet.

31218 to 31220. CITRUS AURANTIUM SINENSIS L. **Orange.**

31218. *Sangtara.* **31220.** *Sylhet.*

31219. *Kaula.*

31221 and 31222. CITRUS DECUMANA (L.) Murr. **Pomelo.**

31221. **31222.** Large fruited.

31223. CITRUS sp.

Malta seed.

31224. DIOSPYROS LOTUS L.

From Lahore, India. Presented by Mr. W. R. Mustoe, superintendent, Government Agri-Horticultural Gardens. Peceived June 6, 1911.

Vernacular name *Lotos amlok.*

31225. CASTILLA sp. **Central American rubber.**

From Vera Cruz, Mexico. Presented by Mr. William W. Canada, American consul. Received June 8, 1911.

Introduced for the work of the Bureau of Plant Industry in encouraging rubber culture in Porto Rico, the Canal Zone, and Hawaii.

31226. CRYPTOCARYA sp.

From Chile. Received through Mr. José D. Husbands, Limavida, Chile, June 9, 1911.

"This fruit is edible and sweet with no ill flavor. The ones I send were dried in the sun to make them harder, as taken ripe from the tree they baffle description; the skin slides at touch revealing a viscous, slimy, ropy-mucous, soapy-mucilaginous jelly, elastic, stringy, and has ways of its own unexampled. It soon dries and shows other qualities. This material may be valuable. It reminds one of rubber, when dried." (*Husbands.*)

31227. CHRYSANTHEMUM MARSCHALLII Aschers.

From Odessa, Russia. Procured from Mr. B. F. Shtamma; presented by Mr. John H. Grout, American consul. Received July 9, 1911.

"A perennial herb belonging to the Compositæ family, closely related to the plant furnishing the Persian insect powder (*Chrysanthemum roseum* W. and M.). The flowers and unopened flower buds, when dried and finely powdered, are used to kill insects, the powder of this species being known also as Persian insect powder. The flowers in some forms are double and give value to the plant as an ornamental. This species occurs with *Chrysanthemum roseum* in the high mountains of the Caucasus, Armenia, and northern Persia, where it occupies sunny areas." (*R. H. True.*)

31228. DRACAENA CINNABARI Balf. f. **Dragon's-blood tree.**

From island of Socotra, Africa. Procured by Mr. Charles K. Moser, American consul, Aden, Arabia. Received May 24, 1911.

"I saw three varieties of this tree growing close together and was much interested in their ruby exudations, of which the natives now make but little use. They call the tree *a'ará-eeib* (as near as I can get it phonetically) and the exudation *mu-soilo.* This tree, I believe, would grow well in the San Bernardino Mountains, of which the Haghier Hills much remind me." (*Moser.*)

"I found the average height of this tree to vary from 18 to 20 feet, and its circumference from 3 to 5. When young they usually have but one stem and no branches, the leaves being disposed in the form of a star round the upper part, but as they get older they may be seen with three, four, and even five stems. From the extremity of each branch a cluster of leaves rises perpendicularly, which are disposed in a circular form radiating from the center. The branches are thickly interwoven in the most fantastic and tortuous shapes, but the foliage, assuming a more regular and better-defined outline, rises in a semicircular shape over the summit. Their appearance at a distance is therefore that of an inverted cone supported by a thin cylinder. The bark of the tree is of a lead color; the wood is soft and spongy, having thin longitudinal fibers extending along it; the roots spread very much, partially intersecting each other near the surface. Few of them extend to any depth, and they may frequently be observed seeking sufficient nourishment from the soil lodged in the cavities in the rocks. The Arabs consider the tree to be of different sexes. The male, they say, produces no gum, which exudes so spontaneously from the female trees that it does not appear necessary on any occasion to make incisions. Soon after the setting in of the southwest monsoon is considered to be the period most favorable for collecting it." (*Wellsted, Travels in Arabia, vol. 2, 1838, pp. 448–451.*)

31229 to 31231.

From Peru. Presented by Mr. J. A. Furlong, Perene, Peru. Received June 9, 1911.

Tubers of the following:

31229. IPOMOEA BATATAS (L.) Poir. **Sweet potato.**

"Grown by the savages in the Perene district." (*Furlong.*)

31230 and 31231. SOLANUM spp. **Potato.**

31230. "Tubers uniform in size, small to medium. Shape uniform, mostly round to oblate, flattened. Surface smooth to knobby. Distal end obtuse to truncate. Stem small to large, central. Proximal end obtuse to truncate. Bud-eye cluster small to large, little too much depressed, central. Cavity rather large, narrow to broad, deep, irregular. Skin thick, tough, not easily bruised, glossy to dull, purple to violet mottled with coppery yellow, variable. Eyes few to many, mostly grouped at distal end, small to large, deep, compound, regular, com-

31229 to 31231—Continued.

31230 and 31231—Continued.

31230—Continued.

pressed, purple. Eyebrows prominent to inconspicuous, short to long, curved. Flesh fine, firm, juicy to dry, white to yellow."

31231. "Tubers uniform and medium in size. Shape uniform, elongated, regular. Surface smooth. Distal end round. Bud-eye cluster small to large, a little depressed, central. Proximal end round. Stem small, deciduous, central. Cavity, none. Skin thick, tough, not easily bruised, dull, purple with coppery cast, uniform. Eyes many, single, large, deep, compound, regular, compressed, purple. Eyebrows prominent to inconspicuous, short to long, straight to curved. Flesh fine, firm, juicy to dry, white to yellow." (*William Stuart.*)

"These potatoes are grown in a place called Huasahuasi, which is 10,000 feet above sea level, by Hill Indians. They are called *Papas de Mesa*, and are much esteemed by the natives. For sowing them the ground is broken by the primitive wooden plow. After it is crossed and drilled for the reception of the seed potatoes they are sown by hand, and after they appear above ground are cultivated by hand hoes of a very primitive pattern, having a wooden handle about 18 inches long. A fine tool to break the backs of any people but Hill Indians." (*Furlong.*)

31236 to 31240.

From Peru. Presented by Mr. J. A. Furlong, Perene. Received June 5, 1911.

Seeds of the following; quoted notes by Mr. Furlong:

31236. TRITICUM AESTIVUM L. **Wheat.**

"From the province of Jauja, department of Junin, grown at an elevation of about 12,000 feet in very poor, stony soil, worked with the primitive wooden plows to a depth of about 4 inches. Is usually sown in drills."

31237. PHASEOLUS VULGARIS L. **Bean.**

"*Frijoles blancos* (white Lima beans). Grow well in almost any kind of soil when sown in the spring of the year. These are grown in the Perene, elevation 2,100 feet."

31238. PROSOPIS JULIFLORA (Swartz) DC. **Algaroba.**

"*Algaroba*, from Tumbes, department of Piura, Peru. This variety grows wild all over the department and forms the principal food of goats, horses, and horned cattle. The tree is being fast killed out by charcoal burners. This seed is part of a lot of 50 pounds brought to the Perene for experimental planting in a dry, sandy soil. The nursery has been made in horse manure, in which the seedlings are coming up fine."

31239. LYCOPERSICON sp. **Tomato.**

"A wild variety found growing in the Perene. Soil very sandy; temperature 80° Fahrenheit in the shade. Elevation 2,100 feet above sea level. The seed was without doubt at one time imported and has now deteriorated. The tomatoes are used exclusively for food purposes. They are about the size of large marbles and are very palatable."

31240. CHENOPODIUM QUINOA Willd. **Quinoa.**

"Grown at 12,000 feet elevation in the province of Jauja; is a food much esteemed by the Cholo Indians; is sown in drills and very lightly covered with earth. It is ready to harvest in about six months, which is done the same as rice and replaces that grain in everything."

31241 to 31268.

From La Mortola, Ventimiglia, Italy. Presented by Prof. Alwin Berger. Received April 5, 1911.

Seeds of the following:

31241. Asparagus acutifolius L. **Asparagus.**

31242. Asparagus cooperi Baker. **Asparagus.**

31243. Asparagus crispus Lam. **Asparagus.**

31244. Berberis japonica bealei (Fortune) Skeels. **Barberry.**

(*Berberis bealei* Fortune, Gardeners' Chronicle, 1850, p. 212.)

This round-leaved form of the Japanese barberry, discovered by Dr. Fortune in a garden in the province of Kiangsu, near Shanghai, China, seems never to have been united with *Berberis japonica*, where it so evidently belongs.

31245. Berberis globosa Benth.

Distribution.—The slopes of the Andes in the vicinity of Bogota, Colombia.

31246. Berberis guimpeli Koch and Bouche.

31247. Buddleia brasiliensis Jacq.

31248. Buddleia globosa Hope.

31249. Buddleia madagascariensis Lam.

Distribution.—Along streams in the Mascarene Islands and in Madagascar; introduced into India, Africa, and South America.

31250. Toona ciliata Roem.

31251. Ceratonia siliqua L. **Carob.**

31252 and 31253. Citrus aurantium sinensis L. **Orange.**

31254. Citrus decumana L. **Pomelo.**

31255. Ilex cornuta Lindl. and Paxton.

See Nos. 22979 and 24638 for previous introductions.

31256. Lygeum sparteum Loefl. **Esparto grass.**

See Nos. 3334 and 21504 for previous introductions.

Distribution.—Southern Europe and northern Africa, extending from Spain and central Italy to Corsica, Sardinia, and Sicily, and through northern Africa from Morocco to Egypt.

31257. Moraea sp.

31258. Moraea iridioides L.

31259. Pistacia lentiscus L. **Mastic tree.**

31260. Psidium araça Raddi. **Araça.**

31261. Quercus suber L. **Cork oak.**

31262. Rosa damascena Miller. **Rose.**

31263. Sabal glabra (Mill.) Sargent.

31264. Sabal blackburnia Glazebrook.

Distribution.—Frequent in the islands of Cuba and Haiti, and the Caribbean group.

31265. Solanum melongena L. **Eggplant.**

Variety *fructo globosa*.

31266. Verbascum olympicum Boiss.

Distribution.—The vilayet of Kastamuni in the northwestern part of Asia Minor.

31267 and 31268. Vitis sp.

31269 to 31271. Meconopsis spp.

From Liverpool, England. Presented by Bees Ltd. Received June 9, 1911.

Seeds of the following:

31269. Meconopsis integrifolia (Maxim.) Franch.

"This striking plant was first discovered by the celebrated Russian traveler, Przewalski, in 1872–73, in the extreme northwest of the province of Kansu, and he subsequently collected it in several different localities in the same region. Potanin also collected it in Kansu, in 1885. In 1887 it was collected by Delavay in the Snowy Range of Likiang, Yunnan, at an altitude of 13,000 feet; and in 1890 Mr. A. E. Pratt obtained very fine specimens in the neighborhood of Tachienlu. Its first appearance in European gardens seems to have been due to the Abbé Farges, who sent seed to Mr. Maurice L. de Vilmorin in 1895, with whom it flowered in 1897, but it produced no seed and was consequently lost to cultivation.

"In 1903 Messrs. James Veitch & Sons sent Mr. E. H. Wilson on a second journey to China, one of the principal objects being to collect seeds of *Meconopsis integrifolia*. He 'found it in millions' in the mountains west of Tachienlu at elevations of 11,000 to 15,500 feet; never lower. As may be expected, it is perfectly hardy in the open ground, but, what was less to be expected, it flourishes and flowers freely without any special treatment. Whether it will seed, time will prove. Under the most favorable conditions in a wild state, Mr. Wilson observed plants about 3 feet high, bearing as many as 18 flowers, while at its greatest altitudinal limit it is reduced to a rosette of leaves with one flower nestling in the center.

"It is a robust biennial, usually 1½ to 3 feet high, densely clothed with long silky hairs varying in color, but usually yellowish brown. Stem stout; branches and peduncles in whorls. Leaves numerous, mostly linear-lanceolate, 6 inches to 1 foot long, shorter on the stem. Peduncles longer than the leaves, one-flowered, clothed with reversed hairs. Flowers yellow, usually 5 to 6 inches in diameter, sometimes as much as 10." (*Extract from Curtis's Botanical Magazine, vol. 1, ser. 4, 1905.*)

Distribution.—Slopes of the mountains in the provinces of Kansu and Yunnan in China.

31270. Meconopsis delavayi Franch.

"This beautiful little plant was first discovered by Pere Delavay in 1884 on the eastern flank of the Lichiang Range, northwest Yunnan, at about 12,500 feet altitude. In height it varies from 5 to 9 inches, reaching the latter only in the most favorable situations. The roots are long, thick, and fleshy. Flowers solitary, semipendulous, 1½ to 2 inches in diameter, color deep, satiny, purple-blue. Mature capsule, erect, 2 to 3 inches in length by ½ inch in diameter. This charming species flowers in June or July, and there is little doubt of its proving perfectly hardy in this (Scotland) climate. The flowers, with their shining, deep-colored petals and orange-colored anthers, form a delightful contrast to the glaucous green of the foliage and scapes. The species is gregarious, and delights in open, sheltered situations. The first specimens found by me formed small, scattered colonies along the base of a series of ragged limestone cliffs, at about 11,000 to 12,000 feet. These were growing on poor, patchy pasture, in the shelter of dwarf bushes and under the lee of rocks. The soil was composed of limestone, gravel, and chips of varying size. The roots of the species are thick and fleshy and, in the exceedingly free formation, penetrate to quite a considerable depth, in many instances as much as 12 to 18 inches. Later in the season the species was met with in greater abundance at a higher

31269 to 31271—Continued.

31270—Continued.

altitude (13,000 to 14,000 feet), growing amongst heavy, alpine pasture in conjunction with *Meconopsis integrifolia* and *M. forrestii*. One peculiar feature of *Meconopsis delavayi* is the remarkable elongation of the scape during the maturation of the capsule; some seen were as high as 2 feet, or nearly four times the normal height of the scape during the flowering period." (*George Forrest, Gardeners' Chronicle, July, 1911.*)

Distribution.—On the slopes of the mountains at an altitude of 12,000 feet in the vicinity of Likiang in the province of Yunnan, China.

31271. MECONOPSIS HORRIDULA RUDIS Prain.

Distribution.—Same as No. 31270.

31272. ERIOBOTRYA JAPONICA (Thunb.) Lindl. **Loquat.**

From Tunis, North Africa. Presented by Mr. L. Guillochon, Jardin d'Essais de Tunis. Received June 12, 1911.

Seeds.

31273. ARRACACIA XANTHORRHIZA Bancr. **Arracacia.**

From Caracas, Venezuela. Presented by Mr. Antonio Valero Lara. Received June 12, 1911.

"This is known by the name of *Yuco* because the color of the stem and leaves is dark and so deep as to be almost black, and there are places where it is known as *Apio negro*. This is made into preparations for the table as legumes are, in a kettle or a glazed pot, for soups, cakes, conserves, and finally a flour is obtained from it called *sulu*, which is highly nutritious for convalescing invalids, babies, and old people." (*Lara.*)

Tubers.

31274. ASPARAGUS HATCHERI Hort. **Asparagus.**

From Hoffmans, N. Y. Purchased from Mr. John C. Hatcher, Amsterdam, N. Y. Received June 12, 1911.

"This variety originated with John C. Hatcher at his greenhouses in Hoffmans, N. Y., some 12 to 14 years ago. The original plant was discovered in a bed of *Asparagus plumosus*, and there is reason to believe that it is a chance hybrid. Mr. Hatcher had been experimenting with asparagus for a number of years before the discovery of this variety, feeling assured that it was possible to produce something superior to *A. plumosus*. About that time he had been crossing several varieties, and his belief is that *Asparagus hatcheri* is the result of a cross between *A. plumosus* and a variety which he ran across in England some 15 years ago.

"Attention was immediately directed to the new plant by reason of its dense and symmetrical growth of dainty, fern-like fronds, the latter being set close together along the stalk and producing splendid fronds averaging 12 to 15 inches or more, as against those of *A. plumosus*, which average from 8 to 10 inches. It is a very free grower, its productive value being as 3 to 1 compared to the old variety, as it will make a string 24 feet long while *A. plumosus* is making one of 8 feet. Its large fronds and lasting qualities make it far superior to the old variety for decorative use. On account of the density of its growth it is much preferred by retailers for bunch work.

"*A. hatcheri* has been given the severest possible test in every direction and stands approved by those who have been fortunate enough to obtain the stock or to use it for decorative purposes." (*Extract from the Florists' Exchange, May 6, 1911, p. 935.*)

31275. SOLANUM TUBEROSUM L. **Potato.**

From Paraguay. Presented by Dr. Moises S. Bertoni, Estacion Agronomica, Puerto Bertoni, Colonia Bertoni, Paraguay. Received June 12, 1911.

Variety *guaraniticum.* "This is a variety of the *Solanum tuberosum* that grows wild in Paraguay and has been confounded with the *Solanum commersonii* of Uruguay. I gave it the name of *Solanum tuberosum* var. *guaraniticum;* see Praelim. ad Floram Guaran., part 1." (*Bertoni.*)

31276 to 31307.

From Chinese Turkestan. Received through Mr. Frank N. Meyer, agricultural explorer, June 3, 1911.

The following seeds and plants:

31276. EUONYMUS sp.

From mountains near Ta-si-ku, Ili Valley, Chinese Turkestan. Altitude, 4,500 feet. "(No. 982, April 8, 1911.) A small, creeping variety, found on northern exposed, grassy mountain slopes and between shrubs on somewhat moist and cool places. Makes stems 3 to 4 feet in length when growing in some well-protected situation. Leaves small, wine red underneath, and semipersistent. Of possible value in northern regions as a ground cover beneath trees. May be expected to be hardier than the ordinary *Euonymus radicans* and its varieties, as the climate of Ili Valley is decidedly of a severe continental nature, e. g., on November 24, 1910, the mercury dropped to −30° C., or −22° F." (*Meyer.*)

31277. IRIS sp. **Iris.**

From near Kizil-Bulak, Tien Shan Range, Chinese Turkestan. Altitude, 7,000 feet. "(No. 983, March 5, 1911.) An iris found on moist, low places at the foot of dry, sun-burned rocks. Of possible value as a garden perennial in uncongenial climates." (*Meyer.*)

31278. IRIS sp. **Iris.**

From mountains near Ta-si-ku, Ili Valley, Chinese Turkestan. Altitude, 4,500 feet. "(No. 984, April 8, 1911.) An iris found on the southern slopes of clayey mountains. Probably dies off early in the season like spring bulbs. Perhaps of value as a spring-flowering perennial in the northern sections of the United States." (*Meyer.*)

31279. MALUS sp. **Apple.**

From hamlet of Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude, 3,700 feet. "(No. 1588a, March 18, 1911.) A wild apple found in abundance in several of the Tien Shan valleys. Apparently of great value as a factor in hybridization work. For further remarks see Nos. 30947, 30948, and 30949." (*Meyer.*)

31280. MALUS sp. **Apple.**

From Kulja, Chinese Turkestan. "(No. 1589a, March 25, 1911.) Seed taken from dried, sliced apples purchased on the local market. Of value like the preceding number." (*Meyer.*)

31281. PRUNUS ARMENIACA L. **Apricot.**

From hamlet of Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude 3,700 feet. "(No. 1590a, March 18, 1911.) Obtained from a Sart settler. Wild apricots occur plentifully here and there in the northern Tien Shan Range. For further remarks see No. 30952." (*Meyer.*)

31276 to 31307—Continued.

31282. Crataegus sp. **Hawthorn.**

From valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude 3,800 feet. "(No. 1591a, March 18, 1911.) A variety found along watercourses in thickets and as solitary specimens." (*Meyer.*)

31283. Sorbus sp. **Ash.**

From near Idin-Kul, Tien Shan Range, Chinese Turkestan. Altitude 8,000 feet. "(No. 1592a, March 10, 1911.) A so-called mountain ash found in cool and shady places at high altitudes. Grows to be a small tree, but is mostly seen as a tall shrub. Possibly of value as an ornamental garden and park tree in regions with long winters and cool summers." (*Meyer.*)

31284. Amelanchier sp.

From near Schutte, Tien Shan Range, Chinese Turkestan. Altitude 7,000 feet. "(No. 1593a, March 10, 1911.) A shrub found on stony mountain sides, often in the shade of tall trees. Grows from 3 to 6 feet tall and bears red berries. Possibly of value as an ornamental garden and park shrub in the northern regions of the United States." (*Meyer.*)

31285. Cotoneaster sp.

From near Kara Tugai, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude 4,000 feet. "(No. 1594a, March 16, 1911.) A shrub occurring in a pebbly bank along the Tekes River. Of robust, dense growth, attaining a height of 5 to 8 feet. Bears blackish red berries which persist a long time. Of value like preceding number." (*Meyer.*)

31286. Cotoneaster sp.

From valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude 3,700 feet. "(No. 1595a, March 18, 1911.) A shrub occurring on rocky slopes; has slender branches 3 to 5 feet in length. Apparently very floriferous, as many of the shrubs were still covered with a multitude of small blackish berries at the time of collecting. Of value possibly like preceding number." (*Meyer.*)

31287. Berberis sp. **Barberry.**

From Tchoa, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude 4,300 feet. "(No. 1596a, March 16, 1911.) A barberry found along the Tekes River on sandy, slightly moist places. Grows from 6 to 10 feet tall and becomes very dense. Leaves entire, somewhat leathery; berries in racemes, small and of red color. The natives use the old wood and root stumps to manufacture a yellow dye. Possibly of value like No. 31284." (*Meyer.*)

31288. Berberis sp. **Barberry.**

From near Ure-Bashi, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude 4,800 feet. "(No. 1597a, March 15, 1911.) A robust-growing species of barberry, occurring on stony places near watercourses. Produces strong stems 8 to 10 feet in length. Leaves small; berries large and apparently of a brownish color. The natives use the stout stems for fencing material and in making artistic lattice work in the ceilings of their dwellings. Possibly of value like No. 31284." (*Meyer.*)

31289. Berberis sp. **Barberry.**

From near Kara Tugai, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude 4,100 feet. "(No. 1598a, March 16, 1911.) A tall-growing barberry occurring in a pebbly bank along the Tekes River. Has large serrated leaves

31276 to 31307—Continued.

31289—Continued.

and long, blue berries which are borne in abundance and are persistent. Of ornamental habits and content with rather sterile soils. Of value like No. 31284." (*Meyer.*)

31290. HALIMODENDRON HALODENDRON (Pallas) Voss.

From near Ure-Dalik, Chinese Turkestan. "(No. 1599a, February 14, 1911.) A spiny Colutealike shrub found on sandy and alkaline places in deserts where the moisture is not too far from the surface; will also stand some shade. Suitable for a hedge plant in regions where long, hot, and dry summers prevail and where the winters are cold. This number is a much more robust form than the one sent under No. 30415." (*Meyer.*)

31291. ROSA sp. **Rose.**

From valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude 3,500 feet. "(No. 1600a, March 19, 1911.) A wild rose growing in semishady places. Has tall, slender branches which are slightly drooping; has very few spines and to judge by the orange-red fruits left on the branches, must be very floriferous. Of value, possibly, as a factor in breeding experiments to create hardier and more floriferous roses for the northern sections of the United States." (*Meyer.*)

31292. ROSA sp. **Rose.**

From Kurgan, Tien Shan Range, Chinese Turkestan. Altitude 7,000 feet. "(No. 1601a, March 5, 1911.) A wild rose found in a very stony and dry bank. Of use perhaps as a stock in dry, cold regions." (*Meyer.*)

31293. CALLIGONUM sp.

From near Schul-Kuduk, Chinese Turkestan. "(No. 1602a, February 21, 1911.) A graceful-looking small desert shrub, having a multitude of slightly bent, very white branches, which are from 2 to 4 feet in length. Occurs in deserts of moving sands, where it builds small mounds. To be tested for its sand-binding capacities in the dry and not too cold sections of the United States." (*Meyer.*)

31294. CLEMATIS sp. **Clematis.**

From near Kizil-Bulak, Tien Shan Range, Chinese Turkestan. Altitude over 6,000 feet. "(No. 1603a, March 4, 1911.) A bushy clematis, occurring on dry, stony, and alkaline places." (*Meyer.*)

31295. IRIS sp. **Iris.**

From near Tuwan, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude 6,000 feet. "(No. 1604a, March 14, 1911.) An iris found on moist low places, said to bear blue flowers. Rhizomes sent under No. 31277, which number see for further remarks." (*Meyer.*)

31296. ASPARAGUS sp. **Asparagus.**

From near Arwat, Tien Shan Range, Chinese Turkestan. Altitude 5,600 feet. "(No. 1605a, March 4, 1911.) A wild asparagus of slightly twining habits, found on sandy alkaline soil. Apparently rare. Possibly of value as an ornamental garden perennial and as a factor in breeding experiments." (*Meyer.*)

31297. ASPARAGUS sp. **Asparagus.**

From Tchoa, Tekes Valley, Tien Shan Range, Chinese Turkestan. Altitude 4,300 feet. "(No. 1606a, March 15, 1911.) A wild asparagus of climbing habits. Rhizomes sent under No. 30953, which number see for further remarks." (*Meyer.*)

31276 to 31307—Continued.

31298. Cucumis melo L. **Muskmelon.**

From Maral-Bashi, Chinese Turkestan. "(No. 1607a, February 16, 1911.) A very fine variety of winter melon, medium large; rind greenish brown; flesh very thick and of pistache color, very sweet in taste; few seeds. To be tested in sections of the United States where the summers are hot and long, the air dry, and where the soil is of a friable, slightly sandy nature and contains a fair percentage of alkaline matter." (*Meyer.*)

31299. Cucumis melo L. **Muskmelon.**

From Maral-Bashi, Chinese Turkestan. "(No. 1608a, February 16, 1911.) A fine winter melon called *Serick Kizlik;* small in size; shape round oblong; rind greenish brown; flesh thick, of a salmon-red color, and of very sweet taste. To be tested like the preceding number." (*Meyer.*)

31300. Cucumis melo L. **Muskmelon.**

From Maral-Bashi, Chinese Turkestan. "(No. 1609a, February 16, 1911.) A very fine winter melon of large size; oblong in shape; rind greenish brown; flesh of a light-salmon color and of an extraordinary thickness; taste fresh sweet, with a slightly saline aftertaste as nearly all the winter melons in Chinese Turkestan have. To be tested like the preceding numbers." (*Meyer.*)

31301. Cucumis melo L. **Muskmelon.**

From Kashgar, Chinese Turkestan. "(No. 1610a, February 3, 1911.) A summer melon called *Ak-Kokchi*, of small size, round shape, and having white meat of very sweet taste. Said to be early. To be tested like preceding numbers." (*Meyer.*)

31302. Cucumis melo L. **Muskmelon.**

From Kashgar, Chinese Turkestan. "(No. 1611a, February 3, 1911.) A summer melon called *Kok-Kokchi;* of small size and round shape; rind and meat both green in color, the latter very sweet and melting. Said to be early. To be tested like preceding numbers." (*Meyer.*)

31303. Medicago falcata L.

From valley of the Chong Djighilan, Tien Shan Range, Chinese Turkestan. Altitude 3,700 feet. "(No. 1612a, March 18, 1911.) A wild yellow-flowered alfalfa. Roots sent under No. 30955, which number see for further remarks." (*Meyer.*)

31304. Medicago sativa L. **Alfalfa.**

From Lou Tchao Ku, Ili Valley, Chinese Turkestan. "(No. 1613a, April 9, 1911.) A wild alfalfa." (*Meyer.*)

31305. Medicago sp. **Alfalfa.**

From near Kurre, Tien Shan Range, Chinese Turkestan. Altitude 7,000 feet. "(No. 1614a, March 13, 1911.) A wild alfalfa. Roots sent under No. 30954, which number see for further remarks." (*Meyer.*)

31306. Vicia sp. **Vetch.**

From Kurre, Tien Shan Range, Chinese Turkestan. Altitude 7,100 feet. "(No. 1615a, March 13, 1911.) A vetch found in wild harvested hay, considered by the natives to be a very nutritious food for cattle, but especially good for horses. To be tested for its possible fodder value in the northern sections of the United States." (*Meyer.*)

31276 to 31307—Continued.

31307. PHASEOLUS VULGARIS L. **Bean.**

From Suiting, Ili Valley, Chinese Turkestan. Altitude 2,400 feet. "(No. 1616a, April 9, 1911.) An uncommon variety of garden bean, probably has been brought in from Kansu. To be tested in cool, elevated regions as a garden vegetable." (*Meyer.*)

31308. CICER ARIETINUM L. **Chick-pea.**

From Guadalajara, Mexico. Presented by Mr. Samuel E. Magill, American consul. Received June 13, 1911.

"*Garbanza Espanola.* This crop is grown without irrigation; about 100 kilos (220.46 lbs.) of seed is used for every 6½ acres and is planted in rows; crop is not cultivated, nor is machinery of any kind used at any time. There is no preparation of the pea for human consumption other than to screen out the largest. As the pea is very hard it must be ground or boiled for a long time for soup before it can be eaten. The small peas not marketable for export are fed to hogs, and the pods and leaves are fed to milch cows. Practically all of the large peas are exported to Spain and Cuba. Recently, however, there has been a demand for them in the United States. The wet season is between June and October, and the dry season from October to June. There is no known insect that interferes with the growth of the plant or the maturing of the pea." (*Magill.*)

31309. ELEPHANTORRHIZA ELEPHANTINA (Burch.) Skeels.

From Springbok Flats, Waterberg District, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, Government agrostologist and botanist, Department of Agriculture, Pretoria, South Africa. Received June 14, 1911.

See No. 25941 for description.

31310. ANNONA CHERIMOLA Miller. **Cherimoya.**

From Peru. Presented by Mr. Geo. W. Baird, Washington, D. C. Received June 16, 1911.

Mr. Baird says these seeds are from the best variety he ever ate.

31311. MAURITIA FLEXUOSA L. f. **Mirity.**

From Brazil. Presented by Mr. Walter Fischer, acting director, Campo de Cultura Experimental Paraense, Para, Brazil. Received June 17, 1911.

"What Wallace says of the fruits (see Bailey's Cyclopedia of American Horticulture, p. 994) is certainly true; I estimated the number of fruits on the compound spadices as high as 500, and I was told that I never saw the largest. These palms are a very conspicuous feature along the Maju River, whence I brought the seeds. I understand that the seeds were once, i.e., before the days of rubber, quite largely exported for making buttons. This is one of the so-called ivory nuts." (*Fischer.*)

"This is a magnificent palm, its cylindrical stems rising like Grecian columns to a height of 100 to 150 feet, terminated by a crown of large fan-shaped leaves, from the base of which is produced a big bunch of pendulous fruits, some measuring 8 to 10 feet in length, weighing 200 to 300 pounds and containing several bushels of fruit. Each fruit is about the size of a small apple, having a reticulated, polished, smooth shell." (*Smith, Dictionary of Popular Names of Plants.*)

Distribution.—In low woods in the northeastern part of South America, extending from Dutch Guiana southeastward to the lower valley of the Amazon.

31312 and 31313. ANACARDIUM OCCIDENTALE L. **Cashew.**

From Bassein, India. Presented by the curator of the Botanical Gardens of the Experimental Farm. Received through Mr. Edwin S. Cunningham, American consul, Bombay, India, June 12, 1911.

Seeds of the following:

31312. Red variety **31313.** Yellow variety.

"In transmission the curator states 'The plant likes perfect drainage. Any sandy soil with few gravels, pebbles, etc., suits the plant to grow. In their natural state they are seen growing on small hills. The root is tapering and does not stand transplanting like Landolphias, unless very carefully attended to. I have seen plants bearing fruit right from the Equator to 23° N. up to an elevation of 3,000 feet.' " (*Cunningham.*)

31314 to 31316.

From Tunis. Presented by Mr. Frank Edward Johnson, Wauregan House, Norwich, Conn. Received June 12, 1911.

Seeds of the following; quoted notes by Mr. Johnson:

31314. HORDEUM VULGARE L. **Barley.**

"*Orge* (barley) grown on the hills around Matmata, southern Tunis, in dry soil. Very little rain in winter; none in spring or summer."

31315. TRITICUM DURUM Desf. **Wheat.**

"Wheat picked in the large oasis near Gabes. Plenty of irrigation."

31316. TRITICUM sp. **Wheat.**

"Native Arab wheat (almost black when ripe) picked by myself at Matmata. Dry soil. No water."

31317. ERYTHRINA POEPPIGIANA (Walp.) Skeels. **Bucare.**

(*Micropteryx poeppigiana* Walp., Linnaea, vol. 23, 1851, p. 740.)

(*Erythrina micropteryx* Poepp.; Urban, Symbolae Antillanae, vol. 1, 1899, p. 327.)

The seeds of this Peruvian leguminous tree were received from Porto Rico under the name *Erythrina micropteryx*. This name was applied to the species by Pœppig on a herbarium specimen, but apparently was not formally published until 1899, when Urban applied it to the plant. But in 1851 Walpers had published the name *Micropteryx poeppigiana*, based on Pœppig's specimen of *Erythrina micropteryx;* and, *poeppigiana* being the earliest published specific name, it is here restored in accordance with the present rules of botanical nomenclature.

From Mayaguez, Porto Rico. Received through Mr. D. W. May, special agent in charge, Porto Rico Agricultural Experiment Station. Received June 16, 1911.

"A leguminous tree of 15 to 20 meters (50 to 65 ft.) beset with short, conical spines; flowers red. Cultivated as a shade tree for coffee and reported from numerous localities in Porto Rico. It is native of the lower Andes of Peru." (*Cook and Collins, Economic Plants of Porto Rico, 1903, p. 139.*)

31318 to 31320. COLOCASIA spp. **Dasheen.**

From Tientai, via Ningpo, China. Presented by Mrs. A. O. Loosley, China Inland Mission. Received June 13, 1911.

Tubers of the following:

31318 to 31320—Continued.

31318. "The tubers of this variety, when cooked, are dry and mealy and are rather whiter than the *Yii-na* variety. The leafstalk is referred to by the Chinese as white." (*Loosley.*)

"The tubers are nonacrid when raw. The flesh and sprouts are white. When cooked the flesh is of fair flavor." (*R. A. Young.*)

31319. "The tubers of this variety when cooked are white at the heart and purplish colored outside. They are stocky and moist. The leafstalk is called *Yü-na* (black). This variety must be grown deep in damp soil (not water), and the earth should be kept banked up. In dry weather they should be watered." (*Loosley.*)

"The tubers are nonacrid when raw. The flesh and sprouts are white. When cooked the tubers are lacking in flavor." (*R. A. Young.*)

31320. "Tuber pink sprouted." (*R. A. Young.*)

31321 to 31323. TRIFOLIUM LUPINASTER L. **Lupine clover.**

From Russia. Received through Prof. N. E. Hansen, South Dakota Agricultural Experiment Station, Brookings, S. Dak., May 20, 1910. Numbered June 17, 1911.

Seeds of the following; notes by Prof. Hansen:

31321. "(H. No. 285). The same as No. 28313. This is selection No. 2, the third generation from one plant; very tall, without branches, but many stems; stems woody."

31322. "(H. No. 286.) The same as No. 28313. This is selection No. 3, the third generation from one plant; plant tall, with single stems and abundance of large leaves."

31323. "(H. No. 287.) The same as No. 28313. This is selection No. 4. The main endeavor with this species is to improve the plant in size and number of leaves. This species of clover is very widely distributed throughout Siberia, ranging to north of the Arctic Circle. It is considered a valuable plant on the native stock ranges."

31325. CITRUS DECUMANA (L.) Murr. **Pomelo.**

From Seharunpur, India. Presented by Mr. William Gollan, February 25, 1904, who was the superintendent of the Botanic Gardens. Numbered June 21, 1911.

"This plant is from one of six scions that were received by the Office of Pomology. The scions were said to comprise three of the best pomelos of India. Nothing more definite than this is known regarding the variety of this tree." (*R. A. Young.*)

31326. MAURITIA SETIGERA Griseb. and Wendl.

From La Brea, Trinidad, British West Indies. Presented by Mr. W. G. Freeman, Acting Director of Agriculture, Port of Spain, Trinidad. Received June 21, 1911.

Distribution.—A gregarious palm, forming the greater part of the vegetation in the swampy parts of the island of Trinidad.

31327. IPOMOEA BATATAS (L.) Poir. **Sweet potato.**

From Auckland, New Zealand. Purchased from Rev. J. H. Simmonds, through Mr. T. W. Adams, Greendale, Canterbury, New Zealand. Received at the Plant Introduction Garden, Chico, Cal., June 7, 1911.

31328. EUGENIA DOMBEYI (Sprengel) Skeels. **Grumichama.**

From Rio de Janeiro, Brazil. Presented by Mr. A. A. Pereira da Fonseca. Received June 23, 1911.

See No. 30040 for previous introduction.

31329. COLOCASIA sp. **Dasheen.**

From Mukden, Manchuria. Presented by Mr. E. C. Parker, Bureau of Agriculture, Industry, and Commerce. Received June 21, 1911.

"The tubers are similar in general character to the usual Japanese type of dasheen. The flesh is nonacrid when raw and when cooked is rather firm in texture and whitish, but has little flavor." (*R. A. Young.*)

31330 to 31352.

From Tcharjui, Russian Turkestan. Presented by Mr. V. A. Paletsky, at the request of Mr. Frank N. Meyer, agricultural explorer. Received through Alexander Heingartner, American consul, Batum, Russia, June 21 and 22, 1911.

Seeds of the following; quoted notes by Mr. Paletsky:

31330. AMMODENDRON CONOLLYI Bunge.

"Collected on drift sands at Repetek, near Tcharjui, Russian Turkestan. A sand binder."

Distribution.—A silvery leaved shrub growing on the shifting sands of the Kizil-Kum Desert near the Aral Sea in central Turkestan.

31331. CALLIGONUM CAPUT-MEDUSAE Schrenk.

"Found on the drift sands near the railway at Farad, near Tcharjui."

See No. 28974 for description.

31332. HALOXYLON AMMODENDRON (C. A. Meyer) Bunge. **Saxaul.**

"Collected on drift sands at Repetek, near Tcharjui."

See No. 28976 for description.

31333. MEDICAGO SATIVA L. **Alfalfa.**

31334. SALSOLA ARBUSCULA Pallas.

"Native throughout Circassia. Collected on drift sands at Farad railway station."

See No. 28973 for description.

31335 to 31352. CUCUMIS MELO L. **Muskmelon.**

From the Tcharjui dunes.

31335. *Ak Beshek.*

31336. *Ananasnaia Koshkarskaia.*

31337. *Azgik.*

31338. *Emirskaia.*

31339. *Gokcha.*

31340. *Guloka.*

31341. *Karakatukh.*

31342. *Khoddja Murash*, in taste one of the best from the Tcharjui dunes.

31343. *Kokani.*

31344. *Megesek.*

31330 to 31352—Continued.

31335 to 31352—Continued.

31345. *Riri Gullik.*

31346. *Saraksi.*

31347. *Zagrakesh.*

31348. *Zami Bucharskaia.*

31349. *Zami Dekani Yrganchi.*

31350. *Zami*, small, early.

31351. *Zarakigiia*, with fragrant sweet juice.

31352. For all qualities one of the best of the Tcharjui dunes. Exported very largely into European Russia. Keeps until April.

31353. GONOCITRUS ANGULATUS (Willd.) Kurz.

From Buitenzorg, Java. Presented by the director, Department of Agriculture. Received June 22, 1911.

Distribution.—In marshy places on the island of Kambangan near the southern coast of Java.

31354. MANGIFERA MACROCARPA Blume.

From Buitenzorg, Java. Presented by the director, Department of Agriculture. Received June 15, 1911.

Introduced for the work of this office in testing new and hardier stocks for the mango.

Distribution.—Known only from the island of Java.

31355 to 31358.

From Taihoku, Formosa. Presented by Mr. G. Takata, Chief of Bureau of Industry, Formosan Government, at the request of Mr. K. Haga, expert, Bureau of Industry. Received May 10, 1911.

Cuttings of the following:

31355. VITIS VINIFERA L. **Grape.**

These are reported to be from vines bearing fruit of unusually high quality for tropical grapes.

31356 to 31358. CITRUS spp.

31356. *Ponkan.*

31357. *Sekkan.*

31358. *Tankan.*

31359. PSIDIUM GUAJAVA L. **Guava.**

From Paraguay. Presented by Mr. C. F. Mead, Villa Encarnacion. Received June 22, 1911.

"A native of South America and cultivated from Buenos Aires to Mexico. In Paraguay it grows wild in great profusion. Will resist cold to the same degree as oranges." (*Mead.*)

31360. CASTILLA LACTIFLUA O. F. Cook. **Central American rubber.**

From Tapachula, Mexico. Presented by Mr. C. A. Lesher, Zacualpa Rubber Plantation. Received June 23, 1911.

Distribution.—The region in the southern part of Mexico in the vicinity of Soconusco and Tapachula.

31361. PERSEA AMERICANA Miller. **Avocado.**

From Chile. Received through Mr. José D. Husbands, Limavida, Chile, June 26, 1911.

"There are two and perhaps three classes in this lot, having green and black-purple skins like some eggplants. They are very highly esteemed and very expensive. These cost me $6 per dozen, Chile money, or $3 gold. They find a ready sale at these high prices. May be shipped when nearly ripe and ripen upon the journey or afterwards. I purchased these, and the friend who sent them ate the fruit for his trouble. They are delicious eaten with salt and pepper and as a salad for breakfast, lunch, dinner, or at any time. Liked better than olives.

"Up to the year 1854 paltas were not considered a comestible fruit and in no way appreciated except as an ornamental tree. The black paltas of Quillota were considered unfit for food for many years afterwards, but now the variety is held in the highest esteem. It is believed to have originated from accidental crossing in the gardens of Quillota with wild Peruvian varieties. In the station of this city one sees paltas offered for sale of many colors, sizes, and shapes: Green, brown, red, russet, etc." (*Husbands.*)

31362. DYERA COSTULATA (Miq.) Hook. f.

From Lawang, Java. Presented by Mr. M. Buysman, Botanic Garden. Received June 19, 1911.

"A Sumatra tree, which produces a surrogate for caoutchouc. A company for the manufacture of articles of this gum is to be formed at Surabaya with a capital of several million florins." (*Buysman.*)

Distribution.—An apocynaceous tree found in Sumatra and other Malayan islands.

31363. DOLICHOS LABLAB L. **Bonavist bean.**

From Paris, France. Purchased from Vilmorin-Andrieux & Co. Received June 27, 1911.

Stringless.

31365. (Undetermined.) **Kiffy.**

From Liberia, Africa. Procured from Mr. Henry Stewart through Mr. G. N. Collins. Received June 23, 1911.

"A cucurbitaceous plant. The seeds of this plant when parched and ground produce a delicious condiment. Kiffy seed is an important ingredient in the popular Liberian dish *dumboy*. The flavor of the parched seed is similar to that of the parched seeds of *Sesamum indicum* which are used in the same way by the natives of Liberia.

"The gourdlike fruits, about the size and shape of a goose egg, are produced on vines like the ordinary gourd. The method of securing the seeds practiced by the Liberians is to macerate the fruits in water and wash them free from the pulp. The season required for maturing the fruit is probably too long to permit the plant being grown anywhere in this country except in the extreme South." (*Collins.*)

31366. EUGENIA sp.

From Paraguay. Presented by Mr. C. F. Mead, Villa Encarnacion. Received June 28, 1911.

"This is called in Guarany *ñangapiri*. Fruit found in the mountains of Paraguay. In size and color same as May Duke cherry; tree also grows to the same height and shape as the one producing this fruit; contains from 1 to 3 seeds and has a button on the bottom similar to the quince. It is beautiful to look at, but the taste is nothing wonderful according to my palate. Tree is found only inside of the forest in shade, so it can not be very resistant to frost." (*Mead.*)

31367. PHORMIUM TENAX Forst. **New Zealand flax.**

From Gore, South Island, New Zealand. Presented by Mrs. Alexander Graham Bell. Received May 8, 1911.

31368 and 31369. TRITICUM AESTIVUM L. **Wheat.**

From the Hoggar region, Algeria. Presented by Dr. L. Trabut, Algiers, Algeria. Received June 28, 1911.

Seeds of the following; quoted notes by Dr. Trabut:

31368. "Wheat, stiffly barbed."

31369. "Wheat, stiffly one-half barbed."

"This wheat was received from among the Hoggar Tuaregs. It is cultivated with the aid of irrigation and in very soft places."

31370. CAPRIOLA DACTYLON (L.) Kuntze. **Bermuda grass.**

From Lucknow, India. Presented by Mr. H. J. Davis, superintendent, Government Horticultural Gardens, at the request of Rev. N. L. Rockey, Gonda, United Provinces. Received June 28, 1911.

Native name *Doob* grass.

NOMENCLATURAL NOTES AND PUBLICATION OF NEW NAMES.

30495. Spondias cytherea Sonnerat.
30498. Warneria augusta Stickman.
30662. Alhagi pseudalhagi (Bieb.) Desv.
30721. Vigna sinensis (Torner) Savi.
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30758. Schizonotus aitchisoni (Hemsl.) Skeels.
30761. Cajuputi hypericifolia (Salisb.) Skeels.
30795. Cajuputi pubescens (Schauer) Skeels.
30993. Circinnus circinatus nummularius (DC.) Skeels.
31115. Phytelephas seemanni O. F. Cook. n. sp.
31244. Berberis japonica bealei (Fortune) Skeels.
31317. Erythrina poeppigiana (Walp.) Skeels.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 243.
B. T. GALLOWAY, *Chief of Bureau.*

HETEROZYGOSIS IN EVOLUTION AND IN PLANT BREEDING.

BY

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[In Cooperation with the Connecticut Agricultural Experiment Station and Harvard University.]

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 20, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 243 of the series of this Bureau a manuscript entitled "Heterozygosis in Evolution and in Plant Breeding," by Dr. E. M. East, Assistant Professor of Experimental Plant Morphology, Harvard University, and Collaborator of this Bureau, and Mr. H. K. Hayes, Plant Breeder of the Connecticut Agricultural Experiment Station. This paper reports results from experiments that have at different times received aid from this Bureau, the Connecticut Agricultural Experiment Station, and the Bussey Institution of Harvard University and should be considered the product of their joint collaboration.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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HETEROZYGOSIS IN EVOLUTION AND IN PLANT BREEDING.[1]

INTRODUCTION.

When a biologist begins any line of genetic work with either plants or animals he generally has occasion to differentiate his stock into more or less pure types by in-and-in breeding. Frequently in the case of animals, and nearly always in the case of plants that are naturally cross-fertilized, he finds there is a loss of vigor, usually unaccompanied by pathological symptoms. This loss of vigor is generally expressed by a decrease in the size of the individual, but it may be shown by a slight decrease in fertility. The phenomenon, although it probably occurs in all great groups reproducing sexually, is not general, however, for in many animals and in plants that are normally self-fertilized it is unnoticeable.

If after obtaining his "pure" stocks the experimenter has occasion to cross strains that differ in character, he often finds that the reverse phenomenon occurs. The vigor of the hybrid is greater than that of either parent.

These manifestations have been noticed for over a century by plant breeders and for probably two thousand years or more by animal hybridizers. Until the end of the nineteenth century the interpretation of the phenomena, if, indeed, that which is only a paraphrased statement of the facts can be called an interpretation, was that deterioration both morphological and physiological is the direct result of inbreeding, and therefore occasional crossing of genetically distinct blood lines is a necessary requisite to vigor in every sexually propagated species.

Seven years ago an extended series of investigations was started at the Connecticut Agricultural Experiment Station having as their primary object an interpretation of these facts in keeping with the more extended knowledge comprised in modern biology. This paper presents a full account of the views that the writers have come to hold through the data gathered in these experiments, although it has not been thought necessary or advisable to confuse the arguments by overloading it with all of the data in their possession. It is hoped that an adequate number of facts are cited to support the thesis, and it is sufficient on this occasion to say that not a single fact has been discovered that is irreconcilable with it."

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[1] Published also as a contribution from the Laboratory of Genetics, Bussey Institution of Harvard University.

THE PROBLEM.

The experimental data upon which the defense of our thesis is based have been obtained entirely from plants, but observations of animal hybrids and published records lead us to believe that the facts are the same among animals. We believe, therefore, that our conclusions apply alike to the animal and the vegetable kingdoms, for we believe the propositions upon which the arguments are based are applicable to all organisms reproducing sexually. These propositions are:

(1) Mendel's law—that is, the segregation of character factors in the germ cells of hybrids and their chance recombination in sexual fusions—is a general law.

(2) Stimulus to development is greater when certain, or possibly all, characters are in the heterozygous condition than when they are in a homozygous condition.

(3) This stimulus to development is cumulative up to a limiting point and varies directly with the number of heterozygous factors in the organism, although it is recognized that some of the factors may have a more powerful action than others.

We later in this bulletin take up briefly some of the specific reasons for extending these theories to the animal kingdom, but at present we shall confine ourselves to developing the botanical proof.

EARLY INVESTIGATIONS.

The number of cases in which hybridizers have noticed an increase in vigor in crosses between subvarieties, between varieties, and between species is so great that an extended citation of the facts is superfluous. Without exception the horticultural writers of the nineteenth century noted the phenomenon and many of them described it at great length. We have taken some trouble to find out its generality, and have found records of its occurrence in the gymnosperms (Darwin,[1] 1876; Focke, 1881) and pteridophytes (Focke, 1881) as well as throughout the angiosperms. In fact, out of 85 families of angiosperms in which artificial hybrids have been made, instances of hybrid vigor exceeding that of the parent species have been noted in 59.

Kŏlreuter (1763), the earliest botanist to study artificial plant hybrids—as Darwin notes—gives many exact measurements of his hybrids and speaks with astonishment of their "statura portentosa" and "ambitus vastissimus ac altitudo valde conspicua." Later, after having been struck with certain natural adaptations for cross-fertilization, he made a passing remark which plainly showed that he thought nature had intended plants to be cross-fertilized and that benefit resulted therefrom. The hybridists that followed Kölreuter were all interested in the phenomenon, but up to the time of Darwin only Knight and Gärtner attempted to generalize from their observations. Perhaps this was because each one noted the fact that some species hybrids were small and weak. Knight (1799), however, made the somewhat generalized statement that nature had something more in view than self-fertilization and intended that sexual intercourse should take place between neighboring plants of the same species. On the whole, however, Gärtner has given the best expression of the views of the botanical experimenters down to 1849, and for this reason we have translated in full his section on "Wachstum, Luxuriation und Sprossungsvermögen der Bastarde" (Gärtner, 1849, p. 526). He writes as follows:

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[1] Citations to literature throughout this bulletin refer to the "Bibliography" on pages 49–51.

> One of the most conspicuous and common characteristics of plant hybrids is the luxuriance of all their parts, a luxuriance that is shown in the rankness of their growth and a prodigal development of root shoots, branches, leaves, and blossoms that could not be induced in the parent stocks by the most careful cultivation. The hybrids usually reach the full development of their parts only when planted in the open, as Kölreuter (1763) has already remarked; when grown in pots and thus limited in food supply their tendency is toward fruit development and seed production.
>
> Concerning the great vigor of hybrids all observers are agreed; on this point may be cited Kölreuter (1763), Sageret (1826), Sabine Berthollet (1827), W. Herbert (1837), Mauz (1825), and Lecoq (1845). The vigor of a plant can even serve to indicate its hybrid nature in a doubtful case, as Kölreuter has done with *Mirabilis jalapo-dichotoma*.
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> Besides possessing general vegetative vigor, hybrids are often noticeable for the extraordinary length of their stems. In various hybrids of the genus Verbascum, for example *lychnitis-thapsus*, the stem shoots up 12 to 15 feet high, with a panicle 7 to 9 feet, the six highest side branches 2 to 3 feet, and the stem 1¼ inches in diameter at the base; in *Althaea cannabino-officinalis* the stem is 10 to 12 feet; in *Malva mauritano-sylvestris* 9 to 11 feet; in *Digitalis purpureo-ochroleuca* 8 to 10 feet, with panicles 4 to 5 feet; and in *Petunia nyctaginifloro-phoenicea* and *Lobelia cardinali-syphilitica* 3 to 4 feet each. Prof. Wiegmann also corroborates these observations.
>
> Hybrids in the genera Mirabilis and Datura are especially conspicuous for their enormous size, as Kölreuter has already stated. The different hybrids of *Datura—Stramonio-tatula, quercifolia-ferox, laevi-tatula,* and *laevi-ferox*—grew so large as to be almost treelike, with branches and leaves that nearly weighed down the stems, even before the time for developing their numerous blossoms. Likewise such species hybrids as *Nicotiana suavolenti-macrophylla, Nicotiana rustica-marylandica,* and *Tropaeolum majus-minus* reach a noteworthy height and circumference.
>
> The root system and the power of germination of hybrids are highly correlated with their great vegetative vigor. Many hybrids, therefore, which are not so luxuriant in growth as those just described, for example, Dianthus, Lavatera, Lycium, Lychnis, Lobelia, Geum, and Pentstemon hybrids, put forth stalks easily and therefore are readily propagated by layers, stolons, or cuttings. The observations of Kölreuter

(1763), Sageret (1826), and Wiegmann (1828) agree with ours in this respect. This extraordinary side branching and tillering, as well as the growth of the main stem, in most hybrids continues until late in the fall and in many until frost, as we have observed in *Lobelia syphilitico-cardinalis*, *Petunia nyctaginifloro-phoenicea*, *Nicotiana suaveolenti-macrophylla*, *Pentstemon gentianoideo-angustifolius*, *Digitalis purpureo-ochroleuca*, *Malva mauritiano-sylvestris*, *Althaea cannabino-officinalis*, etc. Sageret (1826) makes the same statement about *Nicotiana tabaco-undulata*. There are other hybrids, however, that are without this ability to form sprouts, such as *Matthiola annuo-glabra* and those between several Nicotiana species.

Luxuriation expresses itself at times as proliferation; for instance, in *Lychnis diurno-flos cuculi* the receptaculum is changed to a bud that puts forth branches and leaves. If, moreover, the vigor of the hybrids especially affects the stem and the branches, particularly their length, nevertheless the leaves take part in it by becoming larger. Hybrids in the genera Datura, Nicotiana, Tropaeolum, Verbascum, and Pentstemon are examples.

Kölreuter (1763) expresses the opinion that the strength and luxuriance of hybrids continued long after blooming rests upon the fact that the plants are not exhausted and worn out by the production of seed. Similarly, Edw. Blyth (1837) sees in the impotence or sterility of animal hybrids the explanation of their great muscular development, while the considerable size which these hybrids reach in comparison with their parents may be interpreted in the same manner, since capons are able to make a like growth.

But if we take into consideration that: (1) Such a sex condition may exist in diœcious plants without resulting in the luxuriance shown by hybrids, then the reason given above may be no adequate explanation of that phenomenon. (2) The luxuriance of the hybrid plants is already present and visible before the development of the flowers, although one may not doubt that the derangement of the sexual activities and of the development of those organs is not without consequences to the inner life of these plants and that there may obtain essential difference between the weakening or the entire suppression of one or the other of the sexual activities of the hybrids and of the normal separation of the sexes. (3) Not all partially fertile and sterile hybrids are gifted with an increased vegetative power, since we have observed several absolutely sterile hybrids with weakened and limited vegetative vigor; for example, *Nicotiana grandifloro-glutinosa*, *N. glutinosa-quadrivalvis*, *N. rustico-suavolens*, *N. suaveolenti-quadrivalvis*, *Dianthus barbato-deltoides*, *D. caucasico-arenarius*, *Verbascum blattaria-lychnitis*, etc.; at the same time many other hybrids keep the growth relationships of the parent plants unchanged. (4) Among all the hybrids that we have observed, those which show the greatest luxuriance in all their parts are precisely those which show the greatest fertility, for example, *Datura stramonio-tatula*, *Datura quercifolio-ferox*, *Tropaeolum majus-minus*, *Lavatera pseudolbio-thuringiaca*, *Lycium barbaro-afrum*, and *Mirabilis jalapo-dichotoma*. (5) Planting partially fertile hybrids, such as *Nicotiana rustico-paniculata* and *Dianthus barbato-chinensis*, etc., in pots makes the production of fruit and seed easier through limiting the vegetative growth, but a sterile plant is never made fertile by this method. Luxuriance is therefore a peculiar quality of several hybrids, although it is not possessed by all in the same degree.

Although the early hybridizers paid more attention to crosses between distinct species than they did to crosses between races that differed by only a few relatively unimportant characters, there is no question but that they noted a very great number of cases where crosses of the latter character gave plants that were remarkable for their vigor. In fact, we have found no record of intervarietal crosses where delicate or weak hybrids resulted. On the other hand, species crosses sometimes result in hybrids constitutionally feeble. It is obvious, therefore, that a reasonable interpretation of the facts must include an explanation of each category. This matter must be left until later, however, for the work of the early investigators is cited only to show the prevalence of the phenomena under discussion.

Gärtner's researches were followed by but little systematic study of cross and self fertilization in plants until the time of Darwin, and even Darwin's earlier work was confined to the natural means of plant pollination. This early work, mainly a study of pollination in orchids, was summed up in 1862 by the saying "Nature abhors perpetual self-fertilization," a dictum that has become known as the Knight-Darwin law. This important conclusion gave a great impetus to the study of the means of flower pollination throughout the angiosperms. A huge literature of several thousand titles was built up, from which at times important compilations, such as those of Müller (1873) and Knuth (1898), have been made. Every possible variation in flowering habit was argued into an adaptation for cross-fertilization with an ingenuity and zeal similar to that shown by zoologists in their work upon protective coloration and mimicry, and often with as enthusiastic prodigality of extravagant logic. The earnestness of these observers extended our knowledge of the mechanics of pollination in the angiosperms beyond that of any one phase of general botany, yet in the last half of the nineteenth century Darwin was the only scientist who made a systematic experimental inquiry into the physiological effect of cross-pollination compared with self-pollination. The net result of the work of the other observers was simply to show the widespread occurrence of means by which cross-pollination might take place. This fact may be taken to indicate that cross-fertilization is an advantage to a species, but it certainly does not prove that cross-fertilization is indispensable. The many plants naturally self-fertilized preclude it.

Darwin's later experimental work on this subject was so important, both from the standpoint of completeness and brilliancy of analysis, that it must be considered by itself. For this reason we will disregard chronology and conclude this part of our historical summary with the observations of the greatest hybridizer contemporary with Darwin, W. O. Focke. In Focke's fine work "Die Pflanzen-Mischlinge" he gives a chapter on the properties of hybrids, from which the following extract is taken:

> Crosses between different races and different varieties are distinguished from individuals of the pure type, as a rule, by their vegetative vigor. Hybrids between markedly different species are frequently quite delicate, especially when young, so that the seedlings are difficult to raise. Hybrids between species or between races that

are more nearly related are, as a rule, uncommonly tall and robust, as is shown by their size, rapidity of growth, earliness of flowering, abundance of blossoms, long duration of life, ease of asexual propagation, increased size of individual organs, and similar characters.

To undertake a closer examination of the above propositions, it will be necessary to cite a few examples. The following hybrids are abnormally weak: *Nymphaea alba* when crossed with foreign species, Hibiscus, *Rhododendron rhodora* with other species, *R. sinense* with Eurhododendron, Convolvulus, the polyhybrids of Salix, Crinum, and Narcissus. Moreover, it has often been noticed that other hybrid seedlings are somewhat delicate and are brought to maturity with difficulty. Really dwarf growths have been but seldom observed in hybrids; compare, however, certain hybrids of Nicotiana. (Page 285 above, and especially *N. quadrivalvis* × *tabacum macrophylla*, p. 292.) Giant growths are more frequent; note for example Lycium, Datura, Isoloma, and Mirabilis. In size the hybrids generally surpass both the parental species, or at the least they surpass the average height of the two; compare many hybrids of Nicotiana, Verbascum, and Digitalis. Development often goes on with great rapidity, as Klotzsch has emphasized in his hybrids of Ulmus, Alnus, Quercus, and Pinus. Further, the blossoms of hybrids often appear earlier than do those of the parent species, for example, *Papaver dubium* × *somniferum*, many Dianthus hybrids, *Rhododendron arboreum* × *catawbiense*, Lycium, *Nicotiana rustica* × *paniculata*, Digitalis, Wichura's six-fold Salix hybrids, Gladiolus, *Hippeastrum vittatum* × *reginae*, etc., and especially many hybrids of Verbascum. On the contrary, it must be admitted, there are several hybrids that blossom only after a long growth period or not at all, examples of which may be found in the genera Cereus and Rhododendron. Of earlier ripening of the seed independent of earlier blossoming only one example has come down to me, namely Nuphar. Very frequently, one might say very generally, an extraordinary numerical production of flowers has been observed, for example, Capsella, Helianthemum, Tropaeolum, Passiflora, Begonia, Rhododendron, *Nicotiana* (*rustica* × *paniculata*, *glutinosa* × *tabacum*, and others), Verbascum, Digitalis, many of the Gesneraceæ, Mirabilis, and Cypripedium. The size of the blossoms is often increased in hybrids. By crossing two species with flowers of different size, those of the hybrids very nearly reach (not seldom entirely reach) the size of the larger variety. Examples of hybrids with unusually large blossoms are *Dianthus arenarius* × *superbus*, *Rubus caesius* × *bellardii*, and hybrids of *Rosa gallica*, *Begonia boliviensis*, and *Isoloma tydaeum*.

A great capacity for vegetative propagation is very general in hybrids; among the good examples of such a phenomenon may be mentioned Nymphaea, hybrids of *Rubus caesius*, *Nicotiana suaveolens* × *latissima*, *Linaria striata* × *vulgaris*, and Potamogeton. Great longevity may be mentioned as a characteristic of a few hybrids of Nicotiana and Digitalis, ability to withstand cold is especially noticeable in *Nicotiana suaveolens* × *tabacum latissima*, while *Salix viminalis* × *purpurea* is more sensitive to frost than either of the parent species.

These facts point in part to a certain weakness of constitution which is a peculiarity of the hybrid as a result of its abnormal origin and in part to an extraordinary vegetative vigor. An explanation of the last phenomenon, which has been observed much more frequently than the weakness, has only recently been found. The noteworthy experiments of Knight, Lecoq, and others have been familiar for some time, but only through the painstaking experiments of Charles Darwin has the benefit of a cross between individuals and races of one and the same species been clearly demonstrated. The intensification of vegetative vigor in species hybrids is obviously a corresponding experience which requires no especial explanation on the basis of peculiar conditions in hybrids. It was formerly believed that the decreased sexual fertility of hybrids was compensated by a greater vegetative luxuriance, a conception the untenability of which, as Gärtner showed, is refuted in the simplest manner by the experience that many of the most fertile crosses (Datura, Mirabilis) are at the same time characterized by the most excessive stature.

THE WORK OF DARWIN.

Through Darwin's work we get a very different insight into the meaning of cross and self fertilization. At the beginning of his work the knowledge on the subject gained from the experiments and observations of the older hybridists might be summed up in one sentence: Crosses between varieties or between species often give hybrids with a greater vegetative vigor than is possessed by either parent. To be sure there was also a belief that ill effects result from inbreeding, but this belief was generally confined to the animal kingdom. At the end of Darwin's brilliant experiments, or, rather, brilliant analyses of simple but great experiments, not a single point of the many ramifications into which the problem may be divided but had been fully covered. Unfortunately Mendel's experiments were unknown, and the master key of the situation was not available to him. Had it been we can not doubt that he would have made good use of it.

Darwin's interest in the subject arose of course from its connection with the problem of evolution. If the offspring from a cross-fertilization has an advantage over the offspring of a self-fertilization in the struggle for existence, one can hardly doubt the power of natural selection in fixing the structures of flowers. And this being granted, it is obvious that in many flowers mechanical devices to procure cross-fertilization would have been developed. Having found this to be the case in several plants, he bent all his energies to interpreting all flower structures in the same manner. As stated before, the fascination of the work thus initiated has brought us a huge literature on the subject, some of the arguments of which are fantastic to say the least. Darwin himself never allowed his conclusions to get ahead of his facts, a trait that his followers did not always copy. He firmly believed that self-fertilization was so injurious that plants dependent upon it must ultimately perish, but he frankly admitted the obstacles which self-fertilized families like Leguminosæ placed in the way of his conclusions. If he had known of the vigorous plants that reproduce apogamously no doubt he would have regarded the obstacles more seriously than he did. Nevertheless one must admit that at that time, considering the importanco of placing evolution on an impregnable foundation, Darwin did not overstate his conclusions. He proved conclusively the advantage of cross-fertilization and the numerous means by which it is obtained.

If he did not distinguish between the advantage a process may hold forth and the necessity of that process, it was because he was not in possession of all the facts. One does not criticize Darwin, therefore, if in a careful examination of his data in the light of modern knowledge many facts are found that may reasonably have somewhat different interpretations than those originally given.

The first point we will consider is the benefit arising from cross-fertilization. It must be granted from the data already presented that an increase in vigor generally results when different species or markedly different varieties are crossed. It is also perfectly obvious that many plants are naturally designed for cross-fertilization. It can hardly be argued, however, that specific crosses could have had a widespread value in the course of evolution. It must be shown, therefore, that in plants not widely different in character cross-fertilization shows an advantage over self-fertilization. In Table A ("Cross and Self Fertilisation," p. 240) Darwin's results on this subject are given. To be fair, 15 of these experiments should be discarded, because the number of plants measured in the comparison between those crossed and those selfed is less than five. There are 37 experiments left. Of these, the crossed plants were higher in 24 cases, provided an error of 5 per cent is allowed. In 13 cases, then, cross-fertilization showed no definite advantage.

In Table B, where the weights of entire plants are considered, cross-fertilization showed to advantage in 5 experiments out of 8. From these data it seems logical to argue that cross-fertilization between nearly related plants is often a benefit, yet since types that are self-pollinated in nature—legumes, wheat, tobacco, etc.—are among the most vigorous of living plants, it can not be said to be indispensable. Furthermore, about 25 of our most vigorous species of angiosperms have given up sexual reproduction either partially or entirely and have become apogamous.

Did the simple act of crossing produce these beneficial results? If so, why was the advantage due to cross-fertilization not general and without exception? Darwin himself answered these questions. He says (loc. cit., p. 269):

> A cross between plants that have been self-fertilized during several successive generations and kept all the time under nearly uniform conditions does not benefit the offspring in the least, or only in a very slight degree. Mimulus and the descendants of Ipomoea named Hero offer instances of this rule. Again, plants self-fertilized during several generations profit only to a small extent by a cross with intercrossed plants of the same stock (as in the case of Dianthus) in comparison with the effects of a cross by a fresh stock. Plants of the same stock intercrossed during several generations (as with Petunia) were inferior in a marked manner in fertility to those derived from the corresponding self-fertilized plants crossed by a fresh stock. Lastly, certain plants which are regularly intercrossed by insects in a state of nature and which were artificially crossed in each succeeding generation in the course of my experiments, so

> that they can never or most rarely have suffered any evil from self-fertilization (as with Eschscholtzia and Ipomoea), nevertheless profited greatly by a cross with a fresh stock. These several cases taken together show us in the clearest manner that it is not the mere crossing of any two individuals which is beneficial to the offspring. The benefit thus derived depends on the plants which are united differing in some manner, and there can hardly be a doubt that it is in the constitution or nature of the sexual elements. Anyhow, it is certain that the differences are not of an external nature, for two plants which resemble each other as closely as individuals of the same species ever do profit in the plainest manner when intercrossed if their progenitors have been exposed during several generations to different conditions.

In other experiments that Darwin performed it was shown conclusively that crosses between individual flowers borne on the same plant conferred no benefit whatever on the progeny. It is evident, therefore, since plants may differ in nonvisible transmissible characters, that differences in transmissible factors alone account for the benefit produced by crossing and are indispensable to its occurrence. This is clearly shown by the fact that even types naturally self-fertilized, such as the garden pea (*Pisum sativum*), showed a remarkable increase in vigor when entirely different strains were crossed. We may well believe, then, that if Darwin's plants used in his Table A had all been heterozygous at the start they would all have showed a considerable difference in favor of the progeny of those continually cross-fertilized. Furthermore, leaving out of consideration our own beliefs, a study of his own experiments (Ipomoea) shows that if his comparisons had been kept up for a considerable number of generations the cross-fertilized stocks would have become so nearly like the self-fertilized stocks in constitution that the advantage due to cross-fertilization would have been small. But to this point we shall again recur.

Let us now consider whether the known effects of inbreeding and crossbreeding are manifestations of the same phenomenon. In "Animals and Plants Under Domestication" he says (vol. 2, p. 89):

> The gain in constitutional vigor derived from an occasional cross between individuals of the same variety but belonging to different families, or between distinct varieties, has not been so largely or so frequently discussed as have the evil effects of too close interbreeding. But the former point is the more important of the two, inasmuch as the evidence is more decisive. The evil results from close interbreeding are difficult to detect, for they accumulate slowly and differ much in degree with different species, whilst the good effects which almost invariably follow a cross are from the first manifest. It should, however, be clearly understood that the advantage of close interbreeding, as far as the retention of character is concerned, is indisputable and often outweighs the evil of a slight loss of constitutional vigor.

It is obvious that Darwin believed in a definite accumulation of evil effects from self-fertilization, but his experiments do not justify this view. He is perfectly correct in saying that the good effects of crossing are immediately evident. This is clear when it is remembered that if two plants differ in several transmissible allelomorphs the first hybrid generation is heterozygous in all these characters, while future generations as a whole are heterozygous in only part of these characters. Furthermore, one may cross two plants differing but slightly and obtain only a small increase in size; he may then recross with a third plant of widely different nature and obtain a great increase. When one inbreeds, however, he relies on chance combinations to eliminate heterozygosis. This occurs through the action of the laws governing probabilities. Many heterozygous combinations are eliminated at once. This lowers the number of such combinations, and, while the percentage of elimination is the same, the effect of the inbreeding decreases. Complete homozygosis is approached as a variable approaching a limit. It may be illustrated by the old story of the dog decreasing the distance from the hare by half at each jump. The effects of inbreeding, therefore, appear to accumulate, while the effects of crossbreeding are immediately manifest. But is the apparent accumulation of evil effects real? And are the effects evil? Our interpretation is that the effects of inbreeding are not to accumulate ill effects, but to isolate homozygous strains. One does away with a stimulus due to heterozygosis, and one sometimes isolates strains with poor transmissible qualities. But one also isolates good strains; strains that remain good in spite of continued self-fertilization. In other words, the apparent evil effects of self-fertilization decrease directly with the number of generations it is practiced, due to the increase in homozygosis. On the theory entertained by us it should come to an end with complete homozygosis; practically, complete homozygosis is difficult to obtain.

Did such a decrease in deterioration actually occur in Darwin's experiments as they were increased in duration? They did. Darwin himself noted the point. He says ("Cross and Self Fertilisation," p. 55):

> As the plants which were self-fertilized in each succeeding generation necessarily became much more closely interbred in the later than in the earlier generations, it might have been expected that the difference in height between them and the crossed plants would have gone on increasing; but so far was this from being the case that the difference between the two sets of plants in the seventh, eighth, and ninth generations taken together is less than the first and second (and third) taken together.

This statement was made concerning his experiments with *Ipomoea purpurea*, which were continued for 10 generations. The ratio of heights of crossed to heights of selfed plants varied from 100 to 68 in the third generation to 100 to 86 in the fourth generation, but in the ninth generation the ratio was 100 to 79, which is higher than that of the first generation. The tenth generation was indeed low, but it may with all fairness be rejected, for Darwin states that the plants were diseased.

We know, further, that Darwin was not dealing with the same strain at the end of his experiments that he was at the beginning. This change was due, as we now know, to the elimination of Mendelian segregates. The plants in the beginning varied greatly in the color of their flowers. Indeed, they varied during the whole time of experimentation; but the color of the later generations was much more uniform than that of the earlier generations. The selfed generations were so uniform, in fact, that his gardener said "they did not need to be labeled."

In this experiment as well as in those with other species, such as *Mimulus luteus* and *Nicotiana tabacum*, remarkably vigorous self-fertilized types appeared. It may be that new transmissible variations arose, but it is unnecessary to assume it. One may account for every result obtained by Darwin by granting the isolation of homozygous Mendelian segregates, accompanied by loss of the vigor due to heterozygosis through self-fertilization.

RECENT INVESTIGATIONS.

Since the time of Darwin, several writers, whose results will be discussed later, have investigated the effect of inbreeding on animals. Botanists, however, have in general been interested only in the superficial results of inbreeding and crossbreeding and have made no attempts until recently to bring together and to correlate our knowledge regarding them.

In 1905, Shull and the senior writer each started independent investigations concerning the effects of inbreeding in maize, which may be regarded as an ideal cross-fertilized species. To supplement these experiments we have made a large series of crosses with species of the genus Nicotiana which are generally self-fertilized, as well as minor observations on other plants. We will not discuss our previous papers (East, 1907, 1908, 1909, 1910; Hayes and East, 1911) as the present paper gives a résumé of those experiments. Concerning Shull's work (1908, 1909, 1910, 1911), we wish to quote his own conclusions for they are stated very concisely. Furthermore, Shull's data and our own, independently obtained, are corroborative in every detail and therefore have greater weight than either alone. Even the additional conclusions drawn from the data presented in this paper are largely an application of the earlier analysis to the broader problems that are legitimately concerned.

Shull's conclusions up to the year 1910 are summarized by him as follows (Shull, 1910):

> (1) The progeny of every self-fertilized corn plant is of inferior size, vigor, and productiveness as compared with the progeny of a normally crossbred plant derived from

the same source. This is true when the chosen parent is above the average condition as well as when below it.

(2) The decrease in size and vigor which accompanies self-fertilization is the greatest in the first generation and becomes less and less in each succeeding generation until a condition is reached in which there is (presumably) no more loss of vigor.

(3) Self-fertilized families from a common origin differ from one another in definite hereditary morphological characters.

(4) Regression of fluctuating characters has been observed to take place away from the common mean or average of the several families instead of toward it.

(5) A cross between sibs (sister and brother) within a self-fertilized family shows little or no improvement over self-fertilization in the same family.

(6) A cross between plants belonging to two self-fertilized families results in a progeny of as great vigor, size, and productiveness as are possessed by families which had never been self-fertilized.

(7) The reciprocal crosses between two distinct self-fertilized families are equal and possess[1] the characters of the original corn with which the experiments were started.

(8) The F_1 generation from a combination of plants belonging to certain self-fertilized families produces a yield superior to that of the original crossbred stock.

(9) The yield and quality of the crop produced are functions of the particular combination of self-fertilized parental types and these qualities remain the same whenever the cross is repeated.

(10) The F_1 hybrids are no more variable than the pure strains which enter into them.

(11) The F_2 shows much greater variability than the F_1.

(12) The yield per acre of the F_2 is less than that of the F_1.

We should also like to quote Shull (1911) upon one important point upon which we have but few data:

> Necessary corollaries of the view that the degree of vigor is dependent on the degree of hybridity or, in other words, that it is dependent roughly upon the number of heterozygous elements present and not upon any injurious effect of inbreeding per se are (*a*) that when two plants in the same self-fertilized family, or within the same genotype, however distantly the chosen individuals may be related, are bred together there shall be no increase of vigor over that shown by self-fertilized plants in the same genotype, since no new hereditary element is introduced by such a cross; (*b*) that first-generation hybrids produced by crossing individuals belonging to two self-fertilized lines or pure genotypes will show the highest degree of vigor possible in progenies representing combinations of those two genotypes, because in the first generation every individual will be heterozygous with respect to all of the characters which differentiate the two genotypes to which the chosen parents belong, while in subsequent generations recombinations of these characters will increase the average number of heterozygous genes present in each individual; (*c*) that crosses between sibs (sister and brother) among the first-generation hybrids between two genotypes will yield progenies having the same characteristics, the same vigor, and the same degree of heterogeneity as will be shown by the progenies of self-fertilized plants belonging to the same first-generation family.
>
> All of these propositions have now been tested in a limited way. In 1910, nine different self-fertilized families were compared with nine crosses between sibs within the same self-fertilized family; ten crosses between sibs in F_1 families were compared

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[1] They are usually as vigorous or more vigorous than the original strains, but may or may not have the original characters. Some characters may have been entirely eliminated.—E. M. E.

with ten self-fertilizations in the same F_1 families; seven families were raised as first-generation hybrids between individuals belonging to different self-fertilized families; and ten families were grown in which self-fertilization had been entirely precluded during the past five years. The average height of plants in decimeters, the average number of rows per ear, and the average yield in bushels per acre in these 55 families are given in the following table:

	Selfed × self.	Selfed × sibs.	F_1.	F_2.	F_1 × self.	F_1 × sibs.	Cross-breds.
Average height	19.28	20.00	25.00	23.42	23.55	23.30	22.95
Average rows	12.28	13.26	14.41	13.67	13.62	13.73	15.13
Average yield	29.04	30.17	68.07	44.62	41.77	47.77	61.52

An examination of this table indicates to me that on the whole my self-fertilized families are not yet quite pure bred; for the sib crosses give on the average a slightly greater height, number of rows per ear, and yield per acre than the corresponding self-fertilized families as shown by a comparison of the first two columns of the table. The same fact is apparent from a comparison of the "F_1 × self" and "F_1 × sibs" columns, except that in this case the heights and number of rows per ear are essentially equal while the yield per acre is significantly higher in the sib crosses than in the self-fertilized families.

These statements should be sufficient to indicate Shull's work and point of view. Other writers have proposed methods designed to utilize commercially the increase in vigor shown by first-generation hybrids, and at least two other theoretical interpretations of this increase have been submitted (Jost, 1907; and Keeble and Pellew, 1910). These papers will be considered later. We will now take up the data obtained in our own experiments.

EXPERIMENTS ON A NORMALLY CROSS-FERTILIZED SPECIES, ZEA MAYS.

EFFECTS OF INBREEDING.

In these experiments over 30 varieties of maize, including all the varieties widely differentiated from each other, have been artificially self-fertilized for from one to seven generations. In every case a loss of vegetative vigor has followed. At least, following the earlier usage, one may say the result is a loss of vigor if it is kept clearly in mind that pathological degeneration is not what is meant. The universal decline in vigor consists simply in a somewhat less rapid cell division or slower growth and a smaller total amount of cell division resulting in smaller plants and plant organs.

Besides this phenomenon, to which there has been no exception, the progeny always become more or less differentiated in normal morphological characters, although this is less marked in some varieties than in others. For example, from the yellow dent variety known as Leaming various strains differing in the following characters have been isolated during the several generations that they have been inbred:

Red pericarp and colorless pericarp
Red cob and colorless cob.
Red silks and colorless silks.
Red glumes and colorless glumes.
Profusely branched tassels and scantily branched tassels.
Long ears and short ears.
Ears with various numbers of rows.
Ears with large seeds and ears with small seeds.
Ears with straight rows and ears with crooked rows
Ears high on the stalk and ears low on the stalk.
Stalks with many tillers and stalks with few tillers.

Other minor differences have been observed, but these will serve to show just what is meant by "normal differences." There were also differences in yield of seed—described later in this bulletin—some of which may not seem to be normal in character at first thought, but which we hope to show are not less normal than those given above.

Besides these variations, aberrant individuals appeared in a few strains with characters which might well be called abnormal; that is, they are monstrous characters. But this does not mean that they might not have originated in the same manner as normal characters, for they are transmitted as such. Two of these characters, fasciated ears and bifurcated cobs, show a simple Mendelian segregation with incomplete dominance; two others, striped leaves and dwarf plants, are probably recessives. It is possible, however, that one form of striped leaf is the heterozygote between pure white and normal green. It may be that the first two of these abnormalities are not simply isolated as Mendelian segregates. They have also appeared in commercial varieties grown on very fertile soil, a fact that suggests their origin through interference with normal processes of cell division, acceleration in one case and retardation in the other.

The variability of the strains in the above characters decreased as inbreeding was continued, until after four generations they were practically constant for all grosser characters. This does not mean that physiological fluctuation was not as great as in the original strain. It was not reduced in the least degree. Nor can it be said that no new heritable variations arose. Certain variations did appear which may have been new to the strain—witness the fasciated ears—but of this one could not be certain. Furthermore, it is not meant that after four or five generations of inbreeding a type is homozygous in all of its characters. Such a gametic condition is theoretical and could never be recognized in a pedigree culture. But near homozygotes or near homozygous genotypes are obtained without selection simply by inbreeding. The reason for this is simple.

Mendel in his original paper showed that if equal fertility of all plants in all generations is assumed and, furthermore, if every plant is always self-fertilized then in the n^{th} generation the ratio of any particular allelomorphic pair (A, a) would be $2^n - 1\ AA : 2\ Aa : 2^n - 1\ aa$. If we consider only homozygotes and heterozygotes, the ratio is $2^n - 1 : 1$. Of course the matter is not quite so simple when several allelomorphs are concerned, but in the end the result is similar. Heterozygotes are eliminated and homozygotes remain. The probable number of homozygotes and any particular class of heterozygotes in any generation r is found by expanding the binomial $[1 + (2^r - 1)]^n$ where n represents the number of character pairs involved. The exponent of the first term gives the number of heterozygous and the exponent of the second term the number of homozygous characters. As an example, suppose we desire to know the probable character of the fifth segregating generation (F_6) when inbred, if three character pairs are concerned. Expanded we get

$$1^3 + 3[1^2(31)] + 3[1(31)^2] + (31)^3.$$

Reducing, we have a probable fifth-generation population consisting of 1 heterozygous for three pairs; 93 heterozygous for two pairs; 2,883 heterozygous for one pair; 29,791 homozygous in all three character combinations.

From this illustration we think it is fairly easy to see that no matter in how many characters a plant is heterozygous, continued inbreeding will sooner or later eliminate them. Close selection, of course, tends toward the same end, but not with the rapidity or certainty of self-fertilization.

Inbreeding a naturally crossbred plant, then, has these results:

(1) There is partial loss of power of development, causing a reduction in the rapidity and amount of cell division. This phenomenon is universal and therefore can not be related to inheritance. Further, it continues only to a certain point and is in no sense an actual degeneration.

(2) There is an isolation of subvarieties differing in morphological characters accompanying the loss of vigor.

(3) There is often regression away from instead of toward the mean of the general population.

(4) As these subvarieties become more constant in their characters the loss of vigor ceases to be noticeable.

(5) Normal strains with such hereditary characters that they may be called degenerate strains are sometimes, though rarely, isolated.

(6) It is possible that pure strains may be isolated that are so lacking in vigor that the mechanism of cell division does not properly perform its function, and abnormalities are thereby produced.

The maize families shown in Table I illustrate some of these facts, if the yield of shelled corn per acre is taken as a basis of comparison of vigor. These families are not selected to fit a theory, but include representatives of four of the great subdivisions of the species out of those grown in sufficient quantity to give considerable confidence in the determination of yield. Many other types have been inbred for from one to four years, but neither land nor time was available to grow them in large quantities. Their behavior, however, was the same. Inbreeding always reduced the yield of seed and the height and delayed the time of flowering. In general, the decrease in vigor lessened with the inbreeding. Further, both good and bad strains were isolated.

TABLE I.—*Effect of inbreeding on the yield of maize.*

Variety.	Year grown.	Number of years inbred.	Yield in bushels per acre.	Variety.	Year grown.	Number of years inbred.	Yield in bushels per acre.
Watson's flint No. 5	1908	....	75.7	Leaming dent—Contd.			
No. 5–8	1909	1	47.5	No. 1–7–1–1	1908	3	46.0
No. 5–8–3	1910	2	36.1	No. 1–7–1–1–1	1910	4	63.2
Starchy No. 10[1]	1908	....	70.5	No. 1–7–1–1–1–4	1911	5	25.4
No. 10–3	1909	1	56.0	No. 1–7–1–2	1909	3	59.7
No. 10–3–7	1910	2	67.0	No. 1–7–1–2–2	1910	4	68.1
No. 10–3–7–3	1911	3	39.1	No. 1–7–1–2–2–9	1911	5	41.3
No. 10–4	1909	1	43.0	Leaming dent No. 1	1905	....	88.0
No. 10–4–8	1910	2	48.7	No. 1–9	1906	1	42.3
No. 10–4–8–3	1911	3	29.3	No. 1–9–1	1908	2	51.7
Stowell's sweet No. 19	1909	....	93.2	No. 1–9–1–2	1909	3	35.4
No. 19–4	1910	1	58.7	No. 1–9–1–2–4	1910	4	47.7
No. 19–4–7[2]	1911	2	51.2	No. 1–9–1–2–4–6	1911	5	26.0
No. 19–8	1910	1	53.6	Leaming dent No. 1	1905	....	88.0
No. 19–8–2[2]	1911	2	42.1	No. 1–12	1906	1	38.1
Leaming dent No. 1	1905	....	88.0	No. 1–12–1	1907	2	32.8
No. 1–6	1906	1	59.1	No. 1–12–1–1[1]	1908	3	46.2
No. 1–6–1	1908	2	95.2	No. 1–12–1–1–2	1909	4	23.3
No. 1–6–1–3	1909	3	57.9	No. 1–12–1–1–2–4	1910	5	16.5
No. 1–6–1–3–4	1910	4	80.0	No. 1–12–1–1–2–4–11	1911	6	2.0
No. 1–6–1–3–4–4	1911	5	27.7	No. 1–12–1–1–4	1909	4	28.7
Leaming dent No. 1	1905	....	88.0	No. 1–12–1–1–4–14	1910	5	9.5
No. 1–7	1906	1	60.9	No. 1–12–1–1–4–14–3	1911	6	2.0
No. 1–7–1[1]	1907	2	59.3				

[1] Two selections from the progeny of this ear grown.
[2] Probably a normal yield. Grown on a more fertile soil than the rest in 1911.

The different families were all planted on the same plat under uniform conditions each season, but, unfortunately, circumstances made it necessary to grow them upon different fields each season. It is therefore necessary to take into consideration the differences in soil fertility and meteorological conditions each year to see the truth of our conclusions, namely, that continued inbreeding caused only isolation of strains of varying potency. The greatest differences in the environmental conditions were in the years 1908, 1909, and 1911.

In 1908 the land used was highly fertile and the general environmental conditions much above the normal. Four stalks per hill were grown this season, but as only three were grown in other years the actual yields have been reduced one-fourth. Even at this disadvantage the yields in 1908 are probably somewhat high. For opposite reasons, poor soil and badly distributed rainfall, the yields of 1909 are somewhat too low and the yields of 1911 are very much too low. This will be appreciated if the low yields for 1911 are examined in Table III.

Since the data on the Leaming dent variety are the most interesting they are repeated in a somewhat different form in Table II. There they are shown in a regular line of descent.

TABLE II.—*Effect of inbreeding on a variety of Leaming dent maize.*

(Yield, in bushels, of shelled corn per acre.)

Parent variety.	Generations inbred and years in which grown.					
	1	2	3	4	5	6
88.0 (1905)....	59.1 (1906)	95.2 (1908)	57.9 (1909)	80.0 (1910)	27.7 (1911)	....
	60.9 (1906)	59.3 (1907)	46.0 (1906)	63.2 (1910)	25.4 (1911)	....
			59.7 (1909)	68.1 (1910)	41.3 (1911)	....
	42.3 (1906)	51.7 (1908)	35.4 (1909)	47.7 (1910)	26.0 (1911)	....
	38.1 (1906)	32.8 (1907)	46.2 (1908)	23.3 (1909)	16.5 (1910)	2.0 (1911)
				28.7 (1909)	9.5 (1910)	2.0 (1911)

The Leaming, a well-known commercial dent variety, yielded 88 bushels per acre the year before it was first inbred. The season was normal, and this yield may be considered fairly typical of what the variety will do on a moderately good soil. Four ears were inbred and were grown in 1906. This was again an average year. The four strains showed marked decreases in yield and notable differences in their characters. The year 1907 was again an average year, and the second inbred generations are normal. Two strains were not grown as second inbred generations until 1908, however, and they are therefore too high. In 1909 the yields are too low; in 1910 normal, and in 1911 much too low. With these facts in mind, an examination of the tables shows how the strains became more and more differentiated. The first strain, No. 6, is a remarkably good variety of corn even after five generations of inbreeding. It yielded 80 bushels per acre in 1910. The yield was low in 1911, but since all yields were low that year it can hardly be doubted that this strain will continue to produce good normal yields of grain. In the field, even in 1911, the plants were uniformly vigorous and healthy and were especially remarkable for their low variability. The poorest strain, No. 12, is partially sterile, never fills out at the tip of the ear and can hardly exist alone. In 1911 it yielded scarcely any corn but will no doubt continue its existence as a partly sterile variety. Plate I shows ears and tassels of an almost sterile strain isolated by inbreeding.

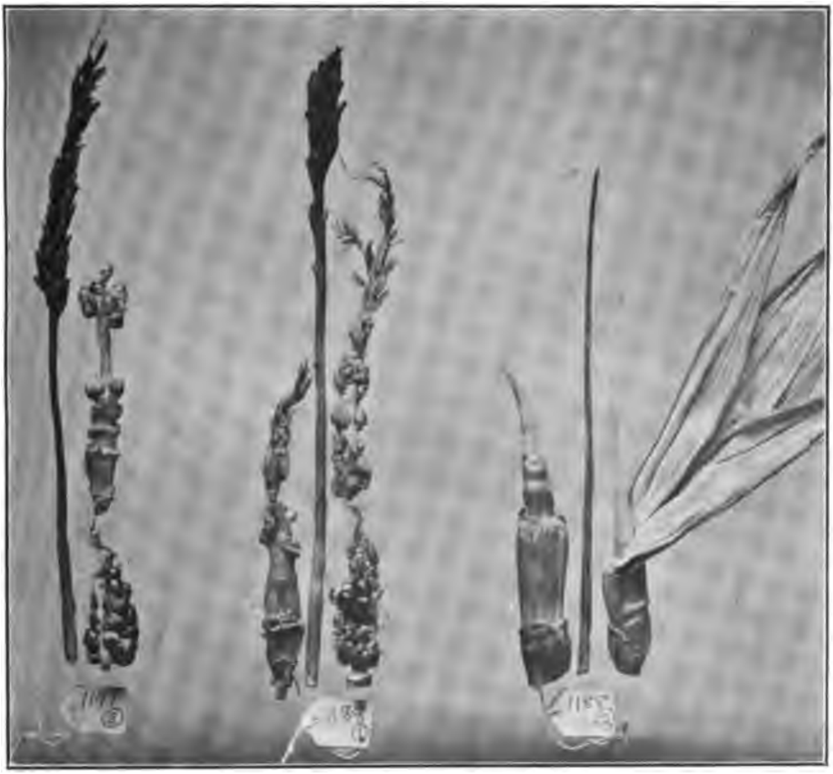
CROSSING INBRED TYPES.

When two of these inbred strains are again crossed, the F_1 generation shows an immediate return to normal vigor. The plants are earlier and taller, and there is a greater total amount of dry matter per plant. For example, in 1911 the average height of all the strains of inbred Leaming dent was 84 inches while the average height of the 16 hybrid combinations was 111 inches and the height of the shortest hybrid combination was 1 foot greater than that of the tallest inbred strain.

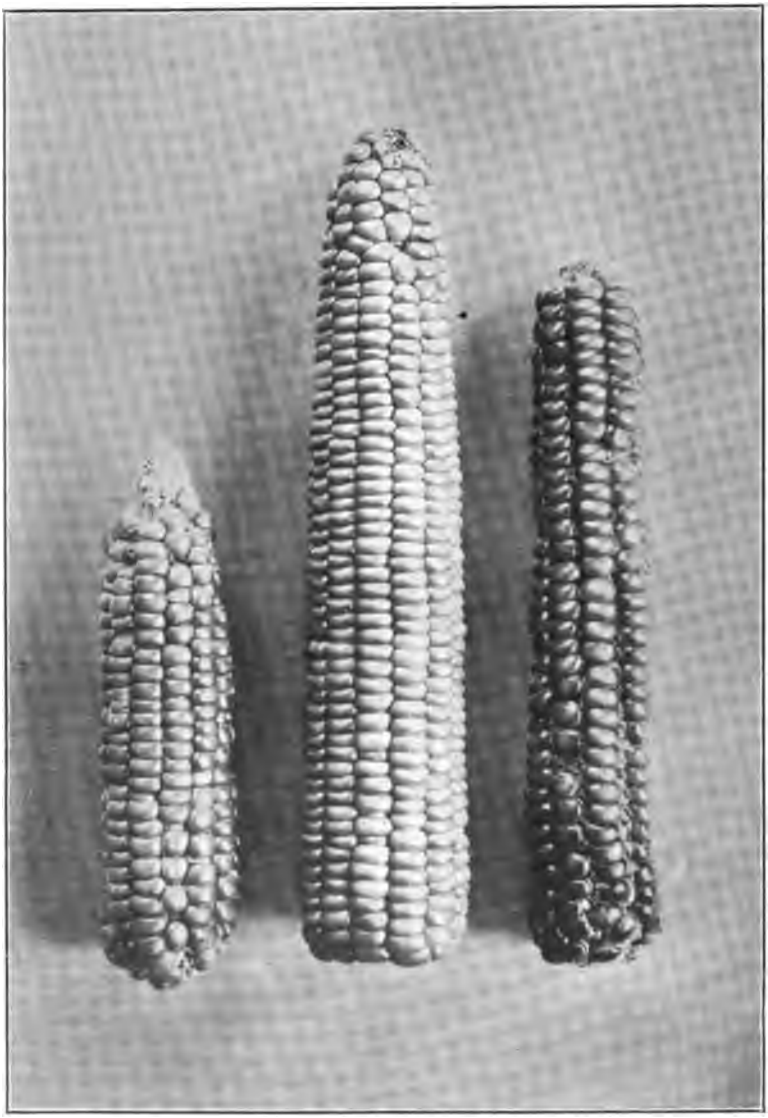
Table III gives the yields of shelled corn per acre of several inbred types, together with the yields of many first-generation crosses. Many interesting points may be learned from this table, provided it is remembered that maize is greatly influenced by environmental conditions and therefore only populations grown in the same season should be compared with each other. For this reason the comparisons between first-generation hybrids and the unselected commercial types from which the inbred strains came are not to be given too great weight. On the other hand, there is such an enormous difference between many of the first-generation hybrids and the normal commercial varieties that the conclusion that the former are often better is perfectly just.

TABLE III.—*Comparative yields of inbred types of maize and their first-generation crosses.*

Variety.	Year grown.	Number of years inbred.	Yield in bushels per acre.	Comparison between F_1 and unselected commercial strains.
White dent No. 8	1908	....	121.0	121.0
Leaming dent No. 1-7	1908	3	62.0	88.0
No. (8×1-7), F_1	1908	....	142.0	142.0
Flint No. 5	1909	1	47.5	75.7
Flint No. 11	1909	1	44.2	48.0
No. (5×11), F_1	1909	....	76.3	76.3
Flint No. 5	1909	1	47.5	75.7
Leaming dent No. 1-6	1909	3	57.9	88.0
No. (5×1-6), F_1	1909	....	88.9	88.9
No. (5×1-6), F_1	1910	....	105.5	105.5
No. (5×1-6)-1, F_2	1910	1	54.1	54.1
No. (5×1-6)-2, F_2	1910	1	48.9	48.9
Starchy No. 10	1910	2	48.7	70.5
Leaming dent No. 1-6	1910	4	80.4	88.0
No. (10×1-6), F_1	1910	....	139.0	139.0



TASSELS AND EARS OF AN ALMOST STERILE STRAIN OF CORN ISOLATED BY INBREEDING.
(Photographed by Emerson.)



WATSON'S FLINT AND LONGFELLOW FLINT CORN INBRED TWO YEARS WITH F_1 HYBRID.

(All ears hand-pollinated.)

TABLE III.—*Comparative yields of inbred types of maize and their first-generation crosses*—Continued.

Variety.	Year grown.	Number of years inbred.	Yield in bushels per acre.	Comparison between F_1 and unselected commercial strains.
Leaming dent No. 1-7	1910	4	65.5	88.0
Sweet No. 19	1910	1	53.6	93.2
No. (1-7×19), F_1	1910		142.7	142.7
Leaming dent No. 1-9	1909	4	23.3	88.0
Leaming dent No. 1-12	1909	3	35.4	88.0
No. (1-12×1-9), F_1	1909		110.2	110.2
No. (1-12×1-9), F_1	1910		117.5	117.5
No. (1-12×1-9)-1, F_2	1910	1	102.2	102.2
No. (1-12×1-9)-4, F_2	1910	1	91.5	91.5
No. (1-12×1-9)-12, F_2	1910	1	91.5	91.5
Leaming dent 1-6	1911	5	27.7	
Leaming dent 1-7-1	1911	5	25.4	
Leaming dent 1-7-2	1911	5	41.3	
Leaming dent 1-9-2	1911	5	26.0	
Leaming dent 1-12-2	1911	6	2.0	
Leaming dent 1-12-4	1911	6	2.0	
No. (1-6×1-7-1), F_1	1911		75.6	
No. (1-6×1-7-2), F_1	1911		58.3	
No. (1-6×1-9-2), F_1	1911		31.6	
No. (1-6×1-12-2), F_1	1911		10.2	
No. (1-7-1×1-6), F_1	1911		58.8	
No. (1-7-1×1-7-2), F_1	1911		41.3	
No. (1-7-1×1-9-2), F_1	1911		51.5	
No. (1-7-1×1-12-2), F_1	1911		16.9	
No. (1-7-1×1-12-4), F_1	1911		60.2	
No. (1-7-2×1-6), F_1	1911		57.7	
No. (1-7-2×1-12-2), F_1	1911		63.5	
No. (1-9-2×1-6), F_1	1911		37.3	
No. (1-9-2×1-7-1), F_1	1911		46.2	
No. (1-9-2×1-12-2), F_1	1911		3.6	
No. (1-12-2×1-7-2), F_1	1911		76.9	
No. (1-12-2×1-12-4), F_1	1911		24.5	

Attention is called first to the fact that in combinations (5×1–6) and (1–12×1–9) both the first and second hybrid generations are grown in the same year. The first hybrid generation gives an enormous increase over the inbred types. The second hybrid generation is also much greater than the inbred strains, but recombination with the production of homozygotes has taken place, and this generation gives much lower yields than when the greatest possible heterozygosity existed as in the first hybrid generation.

Attention should next be directed to the results of 1911, when nearly all the possible combinations of the inbred Leaming strains were made. The yields of the inbred types given are those with one more year of inbreeding than the real parents of the first-generation hybrids. But considering the amount of previous inbreeding to which they had been subjected this probably makes but little difference. As stated before, the yields in 1911 were very much reduced by the unfavorable season, and this too must be given due weight in studying the yields. As a whole the combinations into which No. 1–7 was introduced were the best while those into which the poor type No. 12 was introduced are the poorest. The combination (1–7–1×1–12–4) was, however, a very good cross.

Possibly a question may arise as to whether the fine yields of the combination (1–12×1–9) in 1909 and 1910 and the poor yields of combination (1–9–2×1–12–2) in 1911 are not due to a difference in the behavior of a reciprocal cross. This is probably not the correct reason, for in general there is no difference in reciprocals. No. 1–12 was further inbred when the combinations grown in 1911 were made and this is probably the cause of their poor showing. In the earlier combination, No. 1–12 undoubtedly had a somewhat different gametic constitution than when the later crosses were made. Some essential factor may have been eliminated, therefore, during the further inbreeding. On the other hand, the whole explanation may lie in the poor season of 1911.

The marked increase in productiveness of the F_1 hybrid over the parent inbred types of maize is well shown in Plates II and III, while Plate IV illustrates the falling off in productiveness of the F_2 generation as compared with the F_1 generation from inbred types. Plate V serves to show the striking increase in vigor of the F_1 generation from a cross of pure lines.

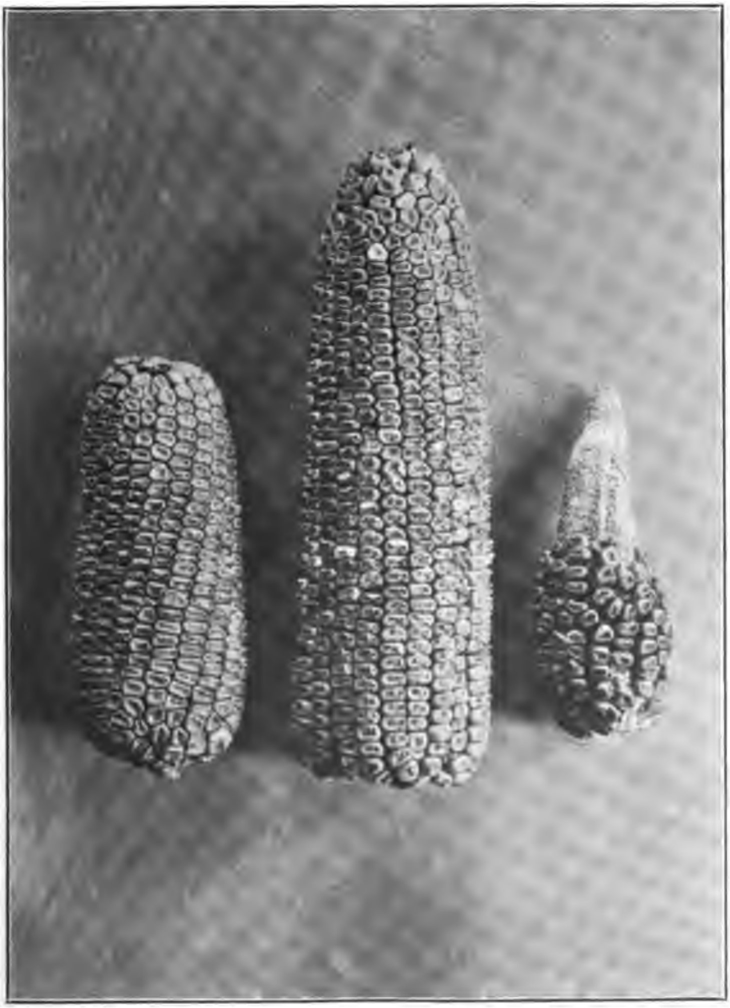
The logical conclusion from the facts brought out above is apparently that good inbred strains are better than poor ones in combination, but that good and poor strains crossed together may give very strong plants.

EXPERIMENTS ON SPECIES GENERALLY SELF-FERTILIZED.

As experimental material that contrasts well with maize, the genus Nicotiana was selected. This genus contains a large number of species and varieties, most of which have flowers adapted to self-fertilization. No doubt cross-fertilization sometimes occurs in most of them, but it is not the rule.

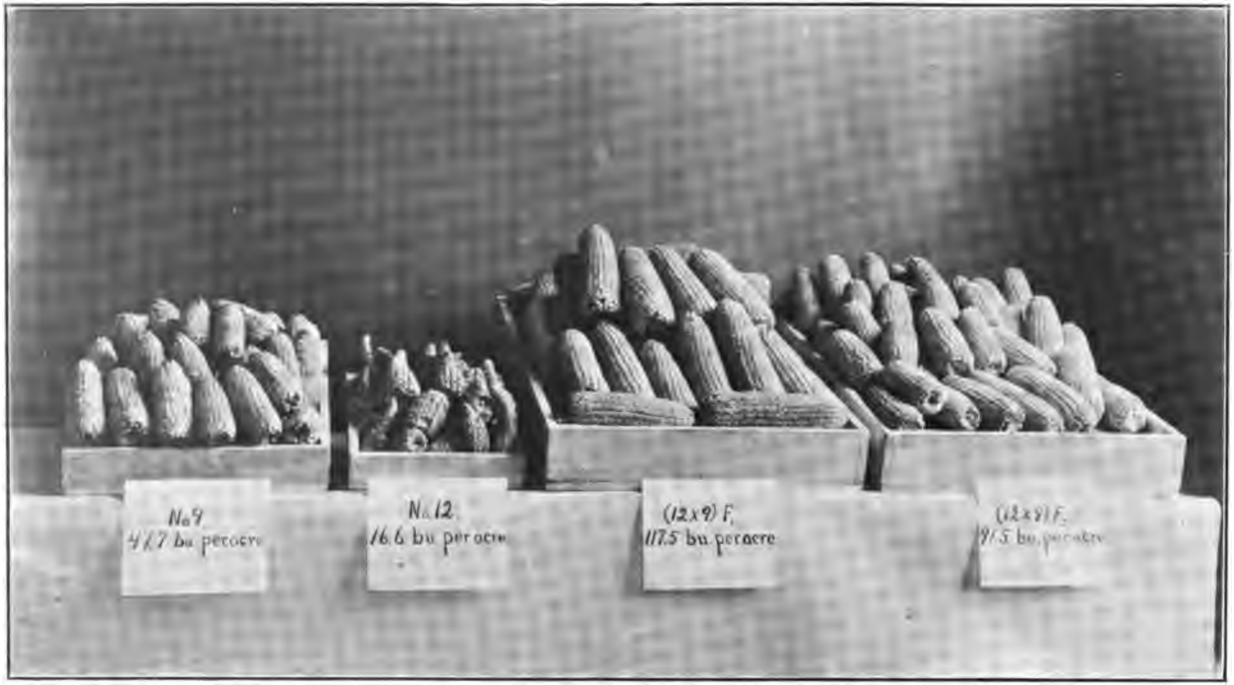
Seeds of several species and many varieties were obtained from various parts of the world through the kindness of a number of friends. The same species did not always arrive with the same name, and we have not been fortunate enough to have the aid of a Nicotiana specialist in their identification. We have, however, studied them in pure-line cultures during the past four years and have compared them with specimens in the Gray Herbarium of Harvard University. This gives us some confidence that the names used are in accord with the species as accepted and described by Comes in his "Monographie du Genre Nicotiana," Naples, 1899.

Many crosses have been made between different varieties within the two species *Nicotiana tabacum*, L., and *N. rustica*, L. Some of the varieties of *N. tabacum* have been practically identical as far as external appearance is concerned, although received under different names. When this has been the case, the results have been varied.



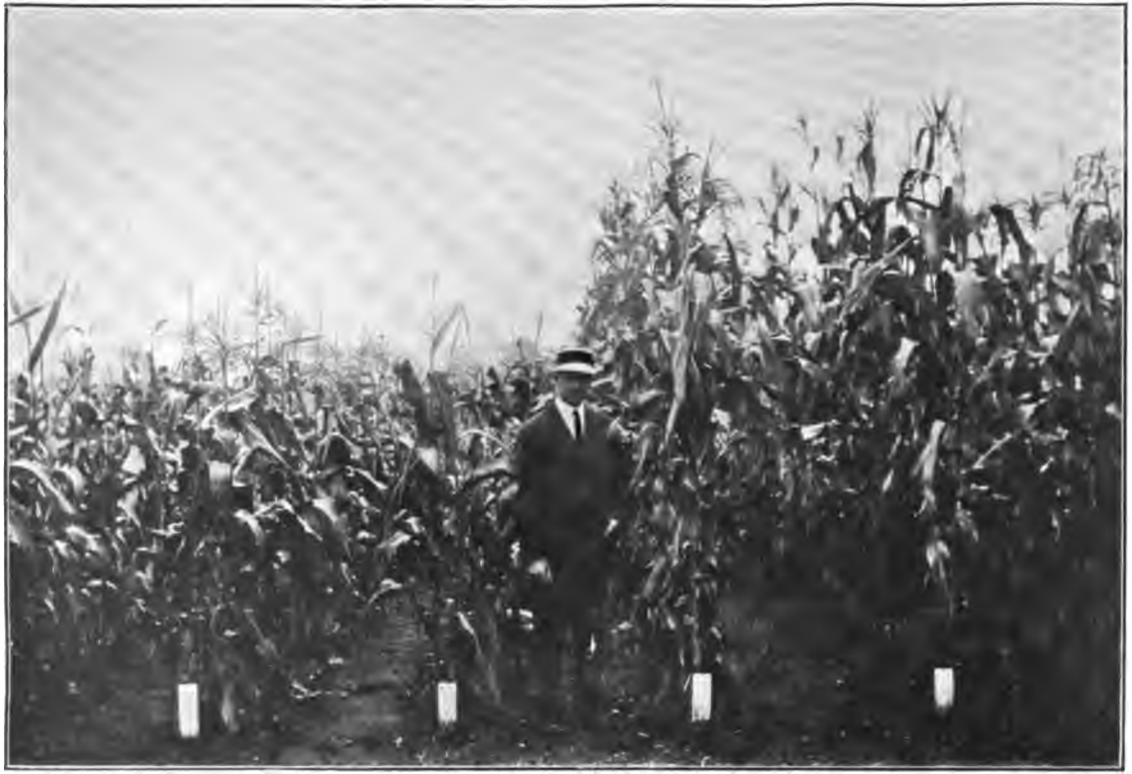
LEAMING DENT STRAINS OF CORN, NO. 9 (AT LEFT) AND NO. 12 (AT RIGHT), AFTER FOUR YEARS' INBREEDING, COMPARED WITH F_1 HYBRID (IN CENTER).

(All ears hand-pollinated.)



INBRED STRAINS OF LEAMING DENT CORN COMPARED WITH F_1 AND F_2 GENERATIONS.

(Grown in 1910.)



STRAINS 6 AND 7 OF LEAMING PURE LINES OF CORN (AT LEFT) AND F_1 GENERATION OF CROSSES 6 X 7-1 AND 6 X 7-2 (AT RIGHT).

(Grown in 1911.)

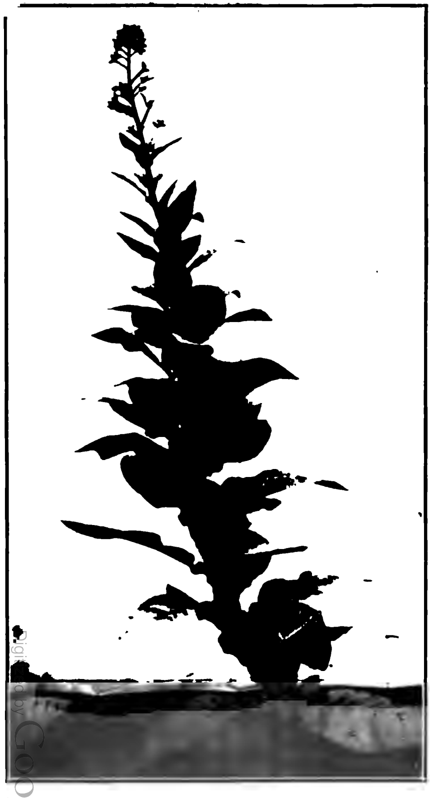


FIG. 1.—NICOTIANA TABACUM VARIETY.

($\frac{1}{32}$ natural size.)

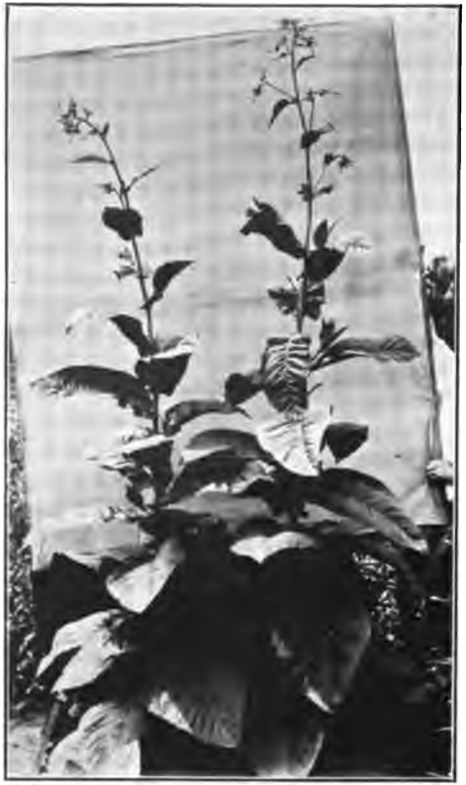


FIG. 2.—NICOTIANA TABACUM VARIETY X N. SILVESTRIS, F_1 GENERATION.

($\frac{1}{30}$ natural size.)

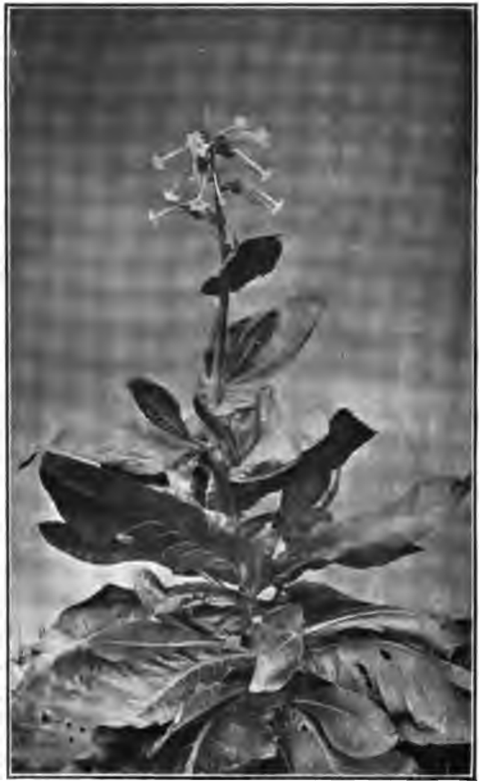


FIG. 3.—NICOTIANA SILVESTRIS.

($\frac{1}{15}$ natural size.)

For example, two exceedingly similar varieties may give hybrids with no greater luxuriance of growth than the pure parent strains; other varieties as similar in appearance may give hybrids with as much as 25 per cent greater vigor than the average of the two parents. In this case the criterion of greater vigor is height of plant. If one accepts the old view that nonrelationship between the individuals used as parents is the reason for the increased vigor of the hybrids, there would be no logical reason why all such crosses should not show the same condition. If, on the other hand, the correct explanation is to be sought in the similarity or dissimilarity of the gametic constitution of the parents, it is quite evident that different crosses among varieties similar in external characters may behave in a different manner. Plants having a close genetic relationship with each other—that is, descendants of a previous cross—may be quite different in gametic constitution and therefore show an increased vigor in the F_1 hybrid; but genetically unrelated plants of practically the same gametic constitution may be obtained from different parts of the world under different names and not be expected to show an increased vigor in the hybrid.

An example of the amount of increase in height in crosses between *Nicotiana rustica brazilia* Comes and *N. rustica scabra* Comes, both obtained from Italy, is shown in Table IV.

TABLE IV.—*Height of crosses between Nicotiana rustica scabra (352) and N. rustica brazilia (349).*

Variety or cross.	Class centers in inches.																		
	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75	78
349	4	10	22	14	7	....	....	....	....	....	....	....	....	....	....	....	....	....	....
352	....	....	....	....	....	....	2	1	5	11	16	17	6	....	....	....	....	....	....
352 × 349 F_1	....	....	....	....	....	....	....	....	....	1	3	0	5	5	5	6	1	1	....
349 × 352 F_1	....	....	...	....	....	....	....	....	....	....	....	3	5	2	4	6	5	1	2

The reciprocal crosses both showed a marked tendency to advance the mode until in each case it is higher than the highest plant of the taller parent. Different strains of *N. tabacum* var. "Sumatra," of *N. tabacum* var. "Havana," and of *N. rustica* var. brazilia, identical in external appearance, obtained both from the same locality and from opposite parts of the world, have also shown increased height when crossed. On the other hand, strains of *N. tabacum* varieties "Sumatra" and "Havana," from seed of plants grown in Connecticut, when crossed with like varieties from seed of plants grown in Italy have shown no increase in vigor. Accounts of other similar crosses could be given, but it seems unnecessary to multiply examples. We will therefore pass to a consideration of the specific crosses shown in Table V.

TABLE V.—*Condition of hybrids in crosses between species of Nicotiana.*

Cross.	Germination.	Fertility.	Condition of hybrid.
	Per cent.		
N. alata Lk. and Otto, var. grandiflora Comes:			
× N. forgetiana Hort. (Sand.)	100	Fertile	25 per cent in height; very vigorous and profuse in flowers.
× N. langsdorffii Weinm	100	do	105 per cent in height; vigorous and profuse in flowers.
× N. longiflora Cav	100	Sterile	100 per cent in height; 100 per cent in vigor.
× N. paniculata L	2	Slightly fertile	80 per cent in height; 80 per cent in general vigor.
× N. tabacum L	3	Sterile(?)	Very weak; seedlings died.
N. bigelovii Wats.:			
× N. alata grandiflora Comes	0		
× N. longiflora Cav	0		
× N. quadrivalvis Pursh	100	Fertile	125 per cent in height; 100 per cent in general vigor.
× N. silvestris Speg. and Comes	0		
× N. tabacum L	100	Sterile	120 per cent in height; 120 per cent in vigor; profuse in flowers.
N. forgetiana Hort. (Sand.):			
× N. alata grandiflora Comes	100	Fertile	125 per cent in height; 130 per cent in general vigor; profuse in flowers.
× N. langsdorffii Weinm	100	do	160 per cent in height; 125 per cent in general vigor; profuse in flowers.
× N. tabacum L	0		
N. glauca Grah. × N. tabacum L	60	Sterile	80 per cent in height; less vigorous.
N. glutinosa L. × N. tabacum L	(?)		Gärtner obtained plants higher and more vigorous than parents.
N. langsdorffii Weinm.:			
× N. alata Lk. Otto, var. grandiflora Comes.	100	Fertile	105 per cent in height; 100 per cent in vigor.
× N. bigelovii Wats	100	Sterile	110 per cent in height; very vigorous.
× N. forgetiana Hort. (Sand.)	100	Fertile	110 per cent in height; 100 per cent in vigor; profuse in flowers.
× N. paniculata L	0		
N. longiflora Cav. × N. alata Lk. and Otto, var. grandiflora Comes.	100	Sterile	100 per cent in height and general vigor.
N. paniculata L.:			
× alata Lk. and Otto, var. grandiflora Comes.	25	Slightly fertile.	95 per cent in height; rather weak.
× N. bigelovii Wats	2	Sterile	100 per cent in height; 95 per cent in vigor.
× N. langsdorffii Weinm	5	do	15 per cent in height; very weak and stunted.
× N. longiflora Cav	0		
× N. rustica L	100	Partially fertile.	125 per cent in height; very vigorous and profuse in flowers.
× N. tabacum L	5	Sterile(?)	Plants very weak and small.
N. plumbaginifolia Viv. × N. longiflora Cav.	100	Fertile	125 per cent in height; 110 per cent in general vigor.
N. quadrivalvis Pursh. × N. bigelovii Wats.	100	do	110 per cent in height; 100 per cent in general vigor; profuse in flowers.
N. rustica L.:			
× N. alata Lk. and Otto, var. grandiflora Comes.	5		So weak that plants lived only about two weeks.
× N. langsdorffii Weinm	80	Sterile(?)	110 per cent in height; 110 per cent in vigor; very profuse in flowers.
× N. paniculata L	100	Partially fertile.	125 per cent in height; very vigorous; profuse in flowers.
× N. tabacum L	5	Sterile	180 per cent in height; extremely vigorous; profuse in flowers.
N. silvestris Speg. and Comes:			
× N. longiflora Cav	0		
× N. tabacum L	100	Sterile	140 per cent in height; 120 per cent in vigor; profuse in flowers.
N. tabacum L.:			
× N. alata Lk. and Otto, var. grandiflora Comes.	2	do	10 per cent of average of parents in height and in general vigor.
× N. bigelovii Wats	100	Almost sterile.	120 per cent of average of parents in height and in general vigor.
× N. glauca Grah	60	Sterile	85 per cent of average of parents in height and 80 per cent in general vigor.
× N. glutinosa L	5		25 per cent of average of parents in height; Gärtner obtained plants more vigorous than parents.
× N. langsdorffii Weinm	10	do	60 per cent of average of parents in height; 75 per cent in general vigor.
× N. longiflora Cav	0		
× N. paniculata L	1		Very small and weak; died before flowering.
× N. plumbaginifolia Viv	0		
× N. silvestris Speg. and Comes	100	Sterile	135 per cent of average of parents in height; 120 per cent in vigor; profuse in flowers.

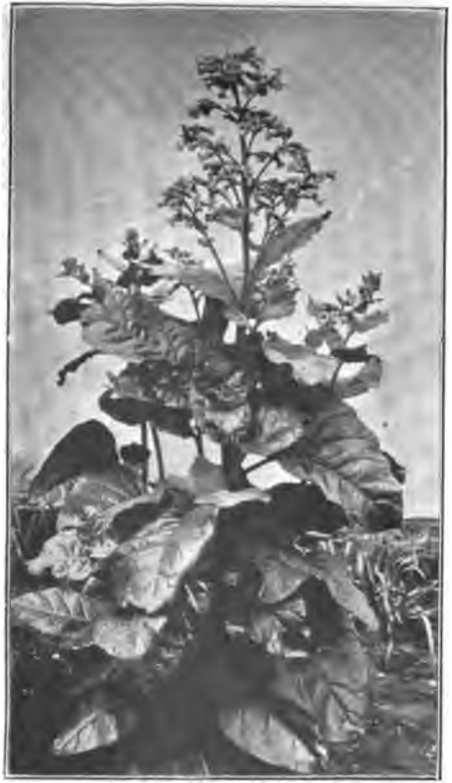


FIG. 1.—NICOTIANA RUSTICA TEXANA.

($\frac{1}{6}$ natural size.)

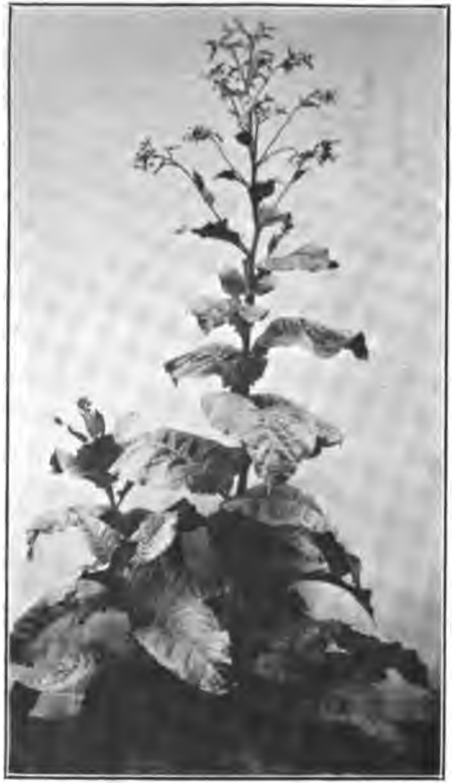


FIG. 2.—NICOTIANA RUSTICA TEXANA × N. TABACUM VARIETY, F1 GENERATION.

($\frac{1}{20}$ natural size.)

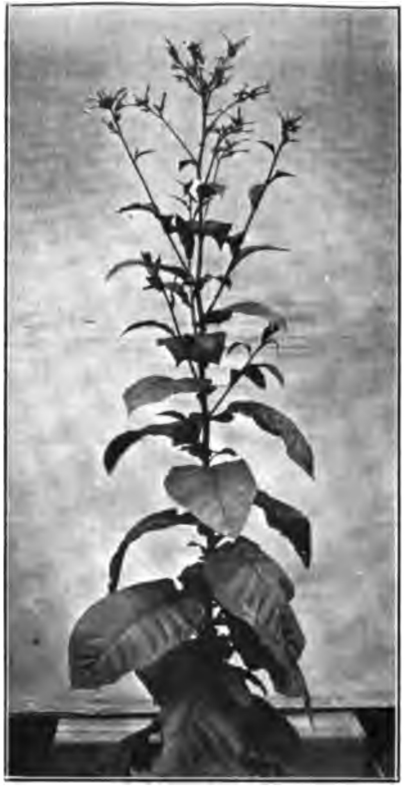


FIG. 3.—NICOTIANA TABACUM VARIETY.

($\frac{1}{18}$ natural size.)

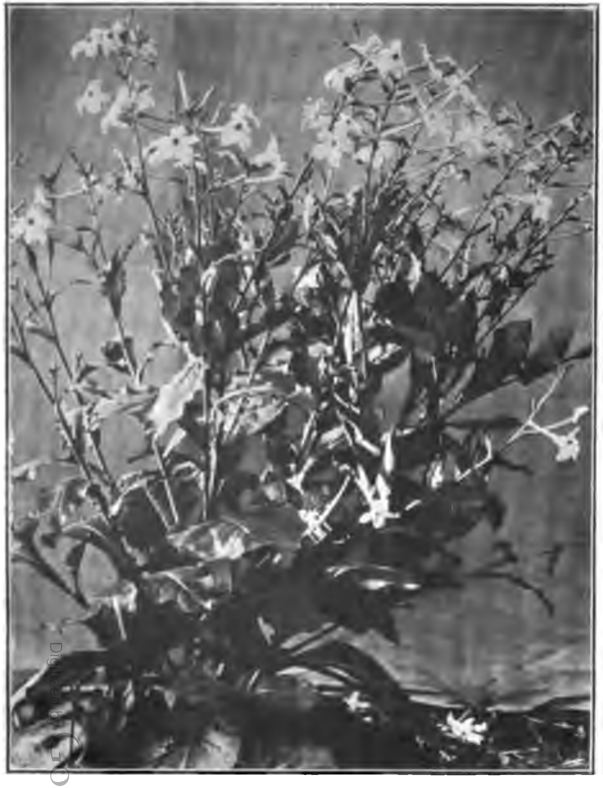


FIG. 1.—NICOTIANA ALATA GRANDIFLORA.

(Twice scale of figure 2.)

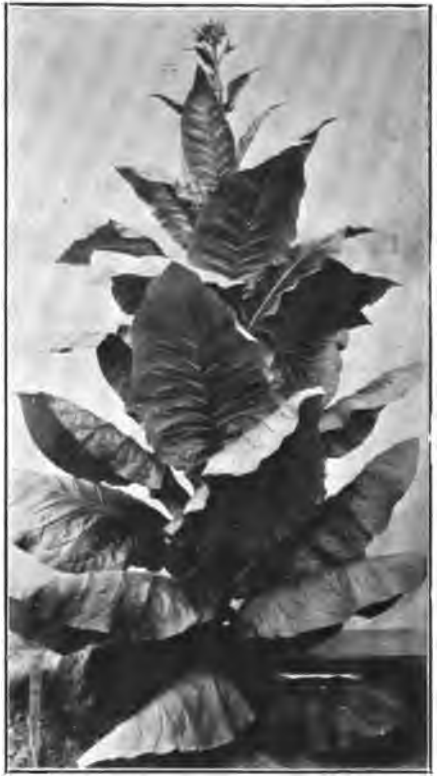


FIG. 2.—NICOTIANA TABACUM VARIETY.

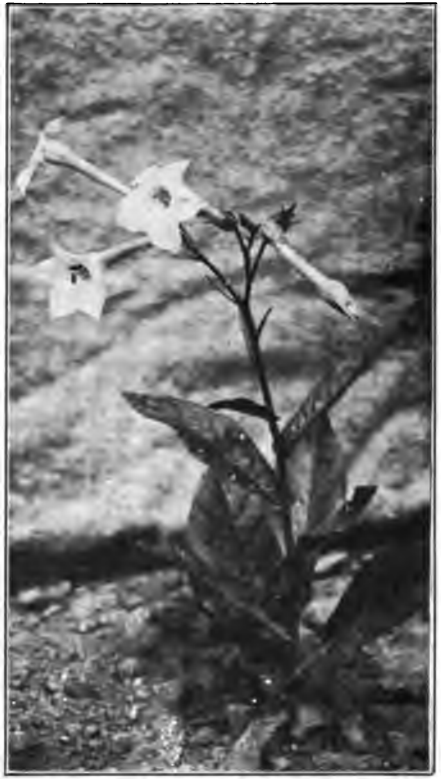


FIG. 3.—NICOTIANA ALATA GRANDIFLORA × N. TABACUM. WEAK AND STERILE HYBRID.

(Six times scale of figure 2.)

The voluminous data that have been collected on these hybrids have been condensed and approximated so that they include only facts germane to the matter in hand. Those crosses designated as not having germinated are crosses in which seed was obtained, but from which no plant was obtained from a planting of at least one hundred seeds. In some of these crosses the seed was poorly formed (without embryo) and one may say conclusively that they would never produce plants. Other crosses gave fully mature, perfect seed which did not germinate. Possibly the proper conditions for their germination were not obtained. At least it would be rash to conclude that all of the crosses of which the seed did not germinate would never produce plants under any conditions. But it is proper to say that some crosses are possible in which the hybrid plant reaches no further than the seed stage. A few hybrids, viz, *Nicotiana tabacum* × *N. paniculata*, *N. rustica* × *N. alata grandiflora*, etc., germinated and produced a few weak plants that died before flowering. There were still others that produced mature plants, but plants shorter than either parent and weak in character. By far the majority of the hybrids, however, were taller than the average of the parents and many were taller than either parent. The luxuriance of their growth was also such that they may be said to be more vigorous than either parent. Plate VI shows the result of a cross between *Nicotiana tabacum*, var., and *Nicotiana silvestris*.

One gets the idea from a survey of the crosses in this genus that there are (*a*) plants so different that they will not cross; (*b*) crosses that produce seed that contain no proper embryo; (*c*) crosses that produce seed with embryo, but which go no further than the resting stage of the seed; (*d*) crosses less vigorous than either parent; (*e*) crosses more vigorous than the average of the parents; and (*f*) crosses more vigorous than either parent. It seems probable, then, that actual fusion may take place between gametes either so different in character that the zygote can not develop or in which the male cell does not bring in the proper substance to stimulate development. On the other hand, when development does take place in a normal manner the great majority of cases show a stimulus greater in the hybrids than in the pure species. Compare Plate VII.

It might be supposed that the luxuriant development of many of these hybrids is due to their sterility, that is, due to the fact that no energy is used in seed formation. Such an idea was held by some of the earlier hybridizers, but was disproved by Gärtner. Nor is it justified by our own experience. Fertile crosses between plants differing in character either equal or exceed the parental vigor; sterile crosses may show a great increase in vigor or they may show a great diminution in vigor. Plate VIII represents a sterile hybrid showing decided diminution in vigor. But there need be no confusion in the interpretation of these facts. It is known that some plants are so unlike that there is mechanical or chemical obstruction to fertilization. In one case the stigmatic fluid may be poisonous to certain foreign pollen; in another case the pollen tubes can not penetrate the micropyle; sometimes nuclei do not enter the micropyle; frequently the two nuclei will not fuse. Such conditions absolutely prevent a cross. On the other hand, where crossing is possible, all of the physiological processes normal to the plant may not be carried out. The difficulty often lies in the maturation of the sex cells, the reduction of the chromatin, and the preparation for a new sexual act. In the proposed parent plants this has already taken place naturally. The male and female gametes are ready for fusion, and if nothing interferes this fusion takes place. But this does not mean that normal development can take place. Cell division may be so difficult that no embryo is formed, there being simply a pericarp formed by the reaction of maternal tissue to stimulation. Again, development of the embryo may take place, primarily because the difficulty of development is decreased through the nutrition furnished by the mother plant. But it may stop at this point. Thus it is obvious that where the parent plants are so different that normal somatic cell division can not take place, weak plants result even though they are heterozygous for many characters. If, however, cell division is normal we may believe that the vigor of the hybrid increases directly with the amount or the kind of heterozygosis present, without regard to whether the plant is sterile or fertile. Sterility, therefore, is often simply an inability to mature the sex elements properly, possibly because of mechanical obstruction to normal reduction of chromosomes differing widely in their character, and sometimes it is correlated with abnormal ontogeny.

We make the statement that hybrid vigor increases with the amount or with the kind of heterozygosis advisedly. The increased vigor may vary roughly with the number of heterozygous characters present, up to that limiting case where the action of other forces prevents or obscures their influence, or it may depend largely upon the quality of the characters that are heterozygous. This matter has not been determined; in reality it makes no difference with the thesis under discussion. It is an interesting problem, but can hardly be tested experimentally by crossing owing to the number of unknown characters that may be present in either a heterozygous or homozygous condition. The proof submitted here rests entirely upon the effects obtained by continued inbreeding as explained by the mathematical expectancy of homozygotes and heterozygotes under continued inbreeding.

One further point ought to be noted here. It has been shown that weak types are sometimes isolated from maize by inbreeding, their delicate constitution being due, it is assumed, to homozygosis of heritable characters that produce weakness and not to the mere fact of inbreeding. Does one obtain weak types in self-fertilized species? Undoubtedly such strains arise, but it is difficult to obtain examples because the weakness of individual plants is usually a physiological fluctuation due to external conditions and is not transmitted. This has been found to be true by growing seedlings from weak plants that have been self-fertilized. They usually give normal plants. Weak strains have been isolated, however, from *Nicotiana tabacum*, from *N. paniculata*, and from *N. attenuata* that continued to transmit their poor constitution. We may conclude, therefore, that weak strains arise in self-fertilized species, but are eliminated by natural selection.

THE CHARACTERS AFFECTED BY HETEROZYGOSIS

The term vigor has hitherto been used with the general meaning which the biologist readily understands. We will now endeavor to show in what plant characters this vigor finds expression. It is not an easy task because of the possibility of confusing the phenomenon of Mendelian dominance with the physiological effect due to heterozygosis. The confusion is due to a superficial resemblance only. Dominance is the expressed potency of a character in a cross and affects the character as a whole. A morphological character like the pods of individual maize seeds, or the product of some physiological reaction like the red color of the seed pericarp in maize may be perfectly dominant, that is, it may be developed completely when obtained from only one parent. Size characters on the other hand usually lack dominance or at best show incomplete dominance. The vigor of the first hybrid generation theoretically has nothing to do with these facts. This is easily demonstrated if one remembers that the increased vigor manifested as height in the F_1 generation can not be obtained as a pure homozygous Mendelian segregate, which would be possible if due to dominance. Furthermore, the universality with which vigor of heterozygosis is expressed as height shows the distinction between the two phenomena. If the greater height were the expression of the meeting of two factors ($T_1t_2 \times t_1T_2$) both of which were necessary to produce the character, one could not account for the frequency of the occurrence. Nevertheless, in practice the confusion exists, and while we have considerable confidence in the conclusions drawn from our experiments, we have no intention of expressing them dogmatically.

It has been stated that the vigor due to heterozygosis is primarily an increase and an acceleration of cell division; in other words, an increased power of assimilation. This is first of all expressed by the increased size of the root system, a fact noticed by Kölreuter and Gärtner as quoted on page 9. This is the first noticeable difference, for the size of the cotyledons of the hybrid is largely influenced by the size of the maternal pericarp, yet there is a slight increase in the cotyledon size, as we have found in experiments with species of the genus Impatiens and with the tomato, *Lycopersicum esculentum.* Hybrid seedlings next show the increased vigor by their rapidity of growth tending toward an earlier maturity. This feature is the acceleration of cell division referred to above. Ultimately, however, there is not only acceleration but increased cell division, resulting in taller plants. Data supporting this fact have already been shown in papers on maize (East, 1911, 1911a). The increased size is entirely internodal. Neither in crosses between maize varieties nor between varieties of *Nicotiana tabacum* is there any tendency to increase the number of nodes. This stem growth is comparatively much greater than is increased leaf surface in the plants investigated (*N. tabacum*), although the latter can be definitely traced.

The size of the flower is not affected, at least not certainly. The fruit also does not seem to be affected where there is a small natural amount of cell division, as in the capsule of tobacco. In fleshy fruits like the tomato or eggplant there is a marked increase. This is probably true also of the large pomes and pepos, but this is only a surmise by analogy.

The increased vigor of the whole plant makes it possible for more flowers and fruit to be produced, as we have determined in tobacco and tomato. A more or less indeterminate inflorescence is always prolonged, which probably accounts for the increased size that is found in the ears of maize hybrids.

There are many less important plant characters upon which no data have been gathered, but the action of heterozygosis is known well enough to justify the former statement that it affects the amount and rapidity of assimilation as expressed by cell division.

THEORETICAL INTERPRETATION OF RESULTS.

At this point it may be well to stop, collect our facts, and discuss their theoretical interpretation, notwithstanding a certain repetition it will involve. We believe it to be established that—

(1) The decrease in vigor due to inbreeding naturally cross-fertilized species and the increase in vigor due to crossing naturally self-fertilized species are manifestations of one phenomenon. This phenomenon is heterozygosis. Crossing produces heterozygosis in all characters by which the parent plants differ. Inbreeding tends to produce homozygosis automatically.

(2) The phenomenon exists and is in fact widespread in the vegetable kingdom.

(3) Inbreeding is not injurious in itself, but weak types kept in existence in a cross-fertilized species through heterozygosis may be isolated by its means. Weak types appear in self-fertilized species, but are eliminated because they must stand or fall by their own merits.

The logical interpretation of all of these facts rests, we believe, on the acceptance of Johannsen's (1903, 1909) "genotype conception of heredity." This conception in turn is an extension of Weismannism[1] without Weismann's mechanistic speculations, supported by Mendelism. Johannsen (1911) gives the essential points of this conception in these paragraphs:

> The personal qualities of any individual organism do not at all cause the qualities of its offspring, but the qualities of both ancestor and descendant are in quite the same manner determined by the nature of the "sexual substances"—i. e., the gametes—from which they have developed. Personal qualities are then the reactions of the gametes joining to form a zygote; but the nature of the gametes is not determined by the personal qualities of the parents or ancestors in question. This is the modern view of heredity.
>
> The main result of all true analytical experiments in questions concerning genetics is the upsetting of the transmission conception of heredity, and the two different ways of genetic research, pure-line breeding as well as hybridization after Mendel's model, have in that respect led to the same point of view, the "*genotype conception*" as we may call the conception of heredity just now sketched.

A simple illustration of what is meant by the above statement is as follows: Suppose a maize with red pericarp (*RR*) be crossed with one with a colorless pericarp (*rr*). In the hybrid the gametes *R* and *r* are formed in equal quantities. By chance mating $1RR:2Rr:1rr$ are obtained. Now the homozygous dominant *RR* is exactly like the heterozygote *Rr* in appearance, but the one breeds true to red pericarp and the other again throws about 25 per cent white progeny. In other words, the gametic composition of the zygotes determines whether the resulting plants shall have ears with red or with colorless pericarps, but the fact that a plant has an ear with a red pericarp does not show what kind of gametes it will form.

The genotype conception of heredity, as stated before, rests on the noninheritance of somatic modifications and the general truth of Mendelism. The first part of the proposition now has almost universal support. All data point to a germ-cell-to-germ-cell hereditary transmission. In certain animals it has been demonstrated that there is an early segregation or setting apart of the material designed to become the germ cells. This fact naturally has been proved in but few animals, but from it one must infer that in all metazoa there is a relative independence of soma and germ plasm undreamed of a few decades ago. In the higher plants no visible difference between germ plasm and soma plasm has been proved, yet the recent experiments of Baur and of Winkler on periclinal chimeras or false-graft hybrids have shown that one of the subepidermal layers is probably alone responsible for the sexual cells. In recent years few biologists have believed that surrounding conditions did not occasionally modify gametic structures. On the other hand, fewer and fewer investigators have maintained that any sort of somatic adaptation would impress the germ plasm with the ability to transmit the same modification.

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[1] One need become a Weismannian only so far as to agree with the observed facts which have shown that the transmission of acquired characters must be so relatively infrequent as to make the possibility negligible in experimental genetics and plant breeding.

The experimental work on the genotype conception of heredity has been largely a demonstration of the last statement. It has shown that in general fluctuations caused by ordinary environmental changes are not inherited. The idea involved is comparatively old. Vilmorin's promulgation of his "isolation principle" in plant breeding in the middle of the nineteenth century might be called its starting point. Vilmorin used the average character of a plant's progeny as the index of that particular plant's breeding capacity. This is the genotype conception, pure and simple. Since that time all plant breeding by selection which has been at all profitable has been done in this way, although the theoretical interpretation of the results obtained was unknown. This was given by Johannsen through his work upon barley and beans.

Since then corroborative results have been obtained by Jennings (1908, 1910) on Paramaecium, Hanel (1907) upon Hydra, Pearl (1909, 1911) upon fowls, Barber (1907) upon yeasts, Woltereck (1909) upon Daphnia, Jensen (1907) upon bacteria, East (1910a) upon potatoes, Love (1910) upon peas, and Shull (1911) and East (1911) upon maize. And no one to my knowledge has made a successful attack upon the position taken. It is true that attacks have been made by Pearson (1910) and Harris (1911), but their main argument is that the genotype theory is wrong, because it antagonizes the utterly erroneous biometric idea that heredity is measured only by the correlation between parents and progeny in somatic characters.

To be sure a caveat has been filed by Castle ("Heredity", New York, 1911) to the effect that unit characters so called can sometimes be modified by selection. This is no real criticism of the genotype conception of heredity, however, for Castle firmly believes in the generality of Mendelism and the general noninheritance of somatic modifications. It must simply be understood that, like most chemical compounds, characters are generally stable under ordinary conditions, but also like chemical compounds they may sometimes be modified. This modification then becomes a new character or is the old character in a slightly different form, depending on the point of view.

The second part of the proposition rests upon the law of segregation and recombination of gametic factors, which is the essence of Mendelism. Every day the generality of this law becomes more probable. Leaving out of consideration experiments on apogamous and parthenogenetic species almost every paper published since 1900 dealing with crosses between varieties fertile inter se in which qualitative differences have been studied has shown that factors representing these characters segregate in the germ cells of the hybrid and recombine in the next generation. The few exceptions have been papers dealing with characters evidently quantitative, treated from a biometrical standpoint and not proving or disproving anything.

Recently there have also been investigations (Emerson, 1910; East, 1910, 1911; East and Hayes, 1911; Lang, 1911, Tammes, 1911) showing that size or quantitative characters also segregate. Of course all selection experiments on cross-fertilized species using Vilmorin's isolation principle and the investigations just cited in support of Johannsen have really proved segregation and recombination of size characters, else strains differing in such characters could not be isolated from complex hybrids. The senior writer (1910), however, has shown how such segregation can be given a strict Mendelian interpretation by postulating absence of dominance and multiplicity of determinants affecting the same general characters. The experimental basis upon which it rests is the investigations of Nillson-Ehle (1909) upon oats and wheat and his own upon maize.

It is possible that there are many apparent exceptions to the law of segregation; it is even possible that practically there are real exceptions, but these exceptions are likely to be in the nature of changed conditions which modify the action of Mendel's law through new sets of conditions. Our meaning is shown by parallels in the domain of physics and chemistry, where certain laws act perfectly only under ideal conditions which are very often not fulfilled in nature. For example, De Vries (1907) states that Burbank's and Janczewski's bramble hybrids have bred true. Without any data upon which to base a critical judgment one does not know what to say, but taking the statement at full value, any number of conditions may cause this hybrid constancy without invalidating the law of segregation. There may be apogamy, all zygotes may not develop, selective fertilization may occur, or the action of the law may be opposed or suspended by other conditions of which we know nothing.

Personally we consider the genotype conception not as a theory but as a fact. Considering it as a fact, how does it aid the interpretation of the results obtained by inbreeding and by crossing inbred types of maize? Maize as a cross-fertilized species of great variability is in a constant state of hybridization. It is a collection of complex hybrids. Its usual mode of pollination through the agency of the wind keeps up this state of hybridization. Inbreeding, however, tends to produce homozygous types. As already shown, if one assumes equal fertility for all plants and that each plant lives and produces offspring in the n^{th} generation there is a ratio 2^n-1 pure dominants, 2 heterozygotes and 2^n-1 pure recessives for each allelomorphic pair.

This theoretical state of affairs may not occur for other reasons (as unpaired chromosomes) and the large number of allelomorphic pairs in a complex hybrid may prolong the time required for isolation of strains that are completely homozygous, but final isolation of strains completely homozygous is the goal toward which inbreeding tends. These completely homozygous strains are Johannsen's homozygous genotypes. Perhaps no one has ever isolated a real homozygous genotype, but strains homozygous for many characters are constantly being separated. This, indeed, is the sole function of selection.

Weismann assigned two purposes to the gametic fusion termed sexual reproduction; one being to mingle the hereditary characters carried by the two germ cells, the other to stimulate development of the zygote. This general statement was so obviously a fact that biologists were unanimous in its acceptance and two distinct lines of investigation have developed from it. Research concerning transmission phenomena has been almost divorced from the study of the physiology of development in its intimate connection with sexual reproduction. This separation, in view of the subject of this bulletin, seems unnecessary and unwise, for it may permit only a partial and distorted view of the results of reproduction. At any rate the data given here are of interest from both view points, since they deal with a purely physiological result brought about by a strictly morphological transmission phenomenon.

The hypotheses in regard to the way by which the act of fertilization initiates development are numerous, but since they are entirely speculative it is not necessary to discuss them here. The only conclusion that seems justified is that they are not immediately psychological or vitalistic in nature. Loeb's remarkable researches prove this. But whatever may be the explanation of the means by which the process is carried out, the statement can be made unreservedly that the heterozygous condition carries with it the function of increasing this stimulus to development. It may be mechanical, chemical, or electrical. One can say that greater developmental energy is evolved when the mate to an allelomorphic pair is lacking than when both are present in the zygote. In other words, developmental stimulus is less when like genes are received from both parents. But it is clearly recognized that this is a statement and not an explanation. The explanation is awaited.

The developmental stimulus is to a certain degree cumulative. In other words, the expression "the greater the degree of heterozygous condition the greater is the vigor of the resulting plant" roughly expresses the facts. This does not mean that the possession of certain allelomorphic pairs in a heterozygous condition is not more necessary than others of normal development. Castle and Little (1910), for example, have shown the probability that zygotes which are potentially homozygous yellow mice are formed but do not develop. Baur (1909) has shown that homozygous recessives of pelargoniums that lack the necessary mechanism for chlorophyll formation are formed but can live only a few days. Of course in the latter case there is actual absence of a physiological mechanism that is absolutely essential to development. Whether the condition is similar in the yellow mice is unknown. It is quite possible that lack of normal or presence of abnormal factors will account for many cases of improper development, but these facts must not be confused with the phenomenon under consideration. What we are concerned with here is that developmental stimulus due to heterozygosity increases roughly with the number of heterozygous allelomorphic pairs, even though some of these pairs may produce a much greater stimulus than others.

Inbreeding, then, tends to isolate homozygous strains which lack the physiological vigor due to heterozygosity. Decrease in vigor due to inbreeding lessens with decrease in heterozygosity and vanishes with the isolation of a completely homozygous strain. Moreover, these homozygous strains can be quite different from each other in natural inherent vigor. From a single strain of Leaming dent maize one isolated type is a good profitable corn after four generations of inbreeding, having yielded at the rate of 80 bushels per acre in 1910; another type is partially sterile and can hardly develop to maturity after five generations of inbreeding, and yielded in 1910 only 9.5 bushels per acre. Thus we see the true explanation of the apparent degeneration that so many observers have attributed to inbreeding per se.

When species that are naturally close fertilized produce variations that are weak and degenerate, they perish in the natural struggle for existence or are not allowed to propagate by man. Since only the experimental breeder sees the origin of degenerate strains of close-fertilized species (as we have done in the genus Nicotiana), biologists have left them out of their consideration and have concluded that some exception to the natural laws of physiology has been made in their favor so that they could stand the inbreeding for which they are naturally fitted. Nothing could be further from the facts. Species which through their flower structure must be self-fertilized produce as many degenerate strains as any species. They are produced, but they do not survive; they are lost and forgotten. Species which through their flower structure are naturally cross-fertilized, on the other hand, produce strains poor in natural vigor, degenerate strains, and they are kept from sight. They survive the scythe of natural selection; they are selected for propagation by man because they are crossed with other strains and are vigorous through heterozygosity. Inbreeding tears aside their mask. They must then stand or fall on their own merits. Those strains with a high amount of inherent natural vigor, due to gametic constitution, lose the added vigor due to a heterozygous condition, but are still good strains, ready to stand up forever under constant inbreeding. The poor strains that have had the help of hybridization with good strains, combined with the added vigor due to heterozygosity, are stripped of all pretense, shown in all their weakness, and inbreeding is given as the cause for their degeneracy. At least inbreeding has until recently been given as the cause, but it is hoped that the newer interpretation will now be accepted as logically interpreting all the facts.

Although the increased power of growth of hybrids and the decreased vigor attending inbreeding have not been recognized as the same phenomenon until the work of Shull and the senior writer, nevertheless there has been a so-called interpretation of the increased vigor of hybrids current among plant physiologists. It is the theory of rejuvenescence or renewal of youth in the protoplasm. Continued self-fertilization is thought to be comparable to vegetative reproduction and continued vegetative reproduction is supposed to bring about a senile condition in the protoplasm. This theory was borrowed from zoology, having long since been proposed by Bütschli to account for conjugation in protozoa. It can not be considered a theory that helps in interpreting the vigor of hybrids, for it tells us nothing. Moreover, it may be based upon wrong premises. It is not at all certain that conjugation is an absolutely necessary phenomenon. Woodruff (1911) has demonstrated that protozoa can be kept in healthy condition without conjugation for at least 2,300 generations. Jennings has been unable to make certain genotypes of Paramaecium conjugate. Nuclear fusions sometimes occur in some of the ascomycetes and basidiomycetes, but in general these fungi reproduce asexually and possibly have produced hundreds of species in this manner. In the higher plants there are many species in which either no seed is produced or sexual propagation is seldom resorted to, and yet they seem to be in no danger of degeneration. Among them may be mentioned the banana, hop, strawberry, sugar cane, and many of the grasses. There are also certain apogamous genera, such as Taraxacum and Hieracium, that are exceedingly vigorous. From these facts it is reasonably conclusive that sexual reproduction may be a benefit, but is not a necessity.

Keeble and Pellew (1910) have recently suggested that "the greater height and vigor which the F_1 generation of hybrids commonly exhibit may be due to the meeting in the zygote of dominant growth factors of more than one allelomorphic pair, one (or more) provided by the gametes of one parent, the other (or others) by the gametes of the other parent." We do not believe this theory is correct. The "tallness" and "dwarfness" in peas which Keeble was investigating is a phenomenon apparently quite different from the ordinary transmissible size differences among plant varieties. Dwarf varieties exist among many cultivated plants, and in many known cases dwarfness is recessive to tallness. It acts as a monohybrid or possibly a dihybrid in inheritance, and tallness is fully dominant. Varietal size differences generally show no dominance, however, and are caused by several factors. Transmissible size differences are undoubtedly caused by certain gametic combinations (East, 1911), but this has nothing to do with the increase of vigor which we are discussing. The latter is too universal a phenomenon among crosses to have any such explanation. Furthermore, such interpretation would not fitly explain the fact that all maize varieties lose vigor when inbred.

EXTENSION OF THE CONCLUSIONS TO THE ANIMAL KINGDOM.

Can the conclusions in regard to heterozygosis be extended to animals? The answer is affirmative as far as an interpretation of the known facts is concerned. No experimental attack from the standpoint taken in this paper has been made, but the older work furnishes many data that readily fit this view. As a matter of fact, however, it is questionable whether it is necessary to make formal proof in the matter. Sexual reproduction has undoubtedly arisen several times in the vegetable kingdom and at least once independently in the animal kingdom. Why or how it arose, one need not inquire; having arisen, the purposes served are essentially the same if the similarity of the methods is an argument. The duplex nature of organisms, the halving of the chromatin and the production of simplex cells at the maturation of the sex cells, the fusion of two simplex cells as the starting point of a new organism, the general result of this fusion in the matter of development, and the transmission of heritable characters, are so similar in their main points that it would be quite wonderful if the process both in plants and animals did not now fulfill like requirements.

Since our conclusions are based upon the generality of Mendelism, which has been rendered highly probable by the multiplicity of zoological researches, it seems only necessary to show that heterozygosis in animals does cause (or accompany) an increase in vigor. It is easier to do this than to attack the still widespread belief that inbreeding is injurious per se. We have seen fertile crosses between different varieties of cattle, of swine, of sheep, and of domestic birds that were more vigorous than either parent. There are several swine raisers in the Middle West who make a practice of selling only first-generation crosses on account of their size. A number of very vigorous sterile hybrids of both domestic and wild animals might also be cited, but with these crosses a complication is encountered. In plants we found that the presence or absence of normal sexual organs made little if any difference in the amount of vigor induced by heterozygosis. In animals the case is undoubtedly different. From their very mode of development—animals being closed forms and plants open forms—internal secretions play a great rôle. And it is a matter of common knowledge that castration, in vertebrates at least, causes an extraordinary development of the body. In the human race this development is especially noticeable in the femur bones, so that Havelock Ellis states that the eunuchs of Cairo can be readily picked out of a crowd by their great stature. It is obvious, therefore, that there are two causes of vigorous somatic development, elimination of sexual organs and heterozygosis. In sterile hybrids, therefore, one can not say how much of the induced stimulation is due to each cause, but in fertile crosses there is no question about its source.

It is much more difficult to argue against the supposed injurious effects of inbreeding. Abhorrence of incest, which probably had a religious origin among our ancestors, is so difficult to eradicate from our minds that judgment is made before the facts are heard. This belief is not universal in the human race if Westermarck, the greatest authority on the history of marriage, is to be trusted, but the retort is made that the races that approve incestuous unions are low in intelligence. The answer does not prove anything, however, as low races with both beliefs are found, and, furthermore, as disapproval of incestuous relations is both religious and esthetic, it would only be expected in races of some intelligence. Nor is the answer germane, for it is not shown that incestuous tribes are less well developed physically than related tribes with different customs, which is the real matter under examination.

But let us confine the discussion to the lower animals. If this is done there are two things to consider, the closeness of matings and their result. The statement is often made that self-fertilization in plants is a much closer sexual relationship than can obtain in bisexual animals. With a germ-to-germ transmission conception of heredity it is doubtful if this is true. After a wide cross, a self-fertilized plant of the F_1 generation produces markedly different progeny, due to recombinations of gametic factors. After continuous self-fertilization for many generations, the gametic factors tend to become homozygous and their matings are close in relationship. Thus it is perfectly clear that it is not kinship of the two organisms furnishing the sex cells that determines the closeness of the mating, but the similarity of the constitution of the cells themselves. There is no a priori reason, therefore, why bisexual animals may not be bred as thoroughly in-and-in as plants.

On this account the statement must be made very emphatic that investigations such as studies of cousin marriages in the human race amount to nothing. A cousin marriage may be a wide cross, it may be very narrow.

There is a possibility that has not been mentioned, however, that may prove to be an essential difference between the reproduction of bisexual animals and hermaphroditic plants. There is no question but that sex in the higher animals is essentially Mendelian in its behavior. There is no necessity of tying its interpretation to the chromosomes or to the accessory chromosome in particular. Castle's (1909) simple explanation that the female is gametically[1] the male plus a theoretical X factor has interpretated so many facts that its correctness—possibly somewhat modified—is highly probable. Under this interpretation one sex is always heterozygous. No similar explanation has been advanced to account for hermaphroditism. Possibly the same thing accounts for the differentiation into microgamete and macrogamete in plants, although not accompanied there by somatic changes. Since we are ignorant of the facts in plants, we can not say that sex furnishes a real reason for believing bisexual animal matings less incestous than plants. The facts are simply given for what they are worth.

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[1] Note the words "gametically the male." This is not at all the same thing as saying *the male plus* something else. The X may produce many important changes during ontogeny.

There are two classes of facts; in one the male is homozygous, having no X factors, while the female has one. In the other the male is heterozygous, having one X factor, while the female is homozygous, with two X factors The human race probably belongs to the second type.

We are now ready to take up the actual effect of inbreeding in animals. In the statements of Darwin's correspondents we find throughout the tendency to mix esthetic feelings and facts. But here and there an independent observer maintained that breeding good stocks in-and-in had no evil effect. Undoubtedly there is sometimes a slight loss in vigor (we should say vegetative vigor as we have done in plants, because constitutional vigor is not lost), but there is no degeneration. On the other hand, there is segregation toward homozygous strains, and these strains differ in constitutional vigor. The greatest breeds of horses, cattle, swine, and sheep have been developed by in-and-in breeding. Breeders have worked for homozygous strains, for they desired strains that bred true. Inbreeding has been accused of producing everything undesirable in many of these strains, but the accusations are extremely illogical. Consider one or two examples. The race horse has undoubtedly been inbred more than the draft horse. Did inbreeding produce the nervousness and delicate constitution of the former? Certainly not. It is absolutely essential that the race horse be nervous. It has been thus selected for generations. Again, the delicate constitution of the Boston terrier or even the toy terrier is pointed out as the effect of inbreeding. We doubt very much if there has been any more inbreeding in the case of the Boston terrier than with the St. Bernard, but the selective ideals have been quite different.

The necessity for heterozygosis may be very different in various species of animals. In some the stimulus to zygotic development may be insufficient when like germ cells conjugate; in others, it may produce normal development. Weismann has made much of the fact that hermaphroditic animals are always cross-fertilized at times. It may be necessary in these species or it may be coincidence. Possibly hermaphroditic species will be found that are always self-fertilized yet retain their vigor even as in plants. At any rate Weismann's arguments seem to have little force, considering the widespread prevalence of parthenogenesis in the animal kingdom. It seems reasonable to conclude that in animals as in plants cross-fertilization may be advantageous but is not a necessity.

The actual experiments of Crampe (1883), Ritzema Bos (1894), and Von Guaita (1898) on mammals, of Fabre-Domengue (1898) on birds, and of Castle et al (1906) on the fly *Drosophila ampelophila* Low may all be interpreted in this way. Fertility was decreased in some strains. Those strains needed the stimulus due to a certain amount of heterozygosis for their proper development. Other strains were perfectly fertile in spite of inbreeding. Sometimes combinations of hereditary characters resulted in relatively weak strains; other combinations of characters gave strong strains. In no case was there absolute and universal degeneration due directly to inbreeding.

As a final example of the simple way in which these experiments on animals fit the heterozygosis theory, we will take a case that puzzled Weismann (1904). Nathusius allowed the progeny of a Yorkshire sow to inbreed for three generations. Weismann says: "The result was unfavorable, for the young were weakly in constitution and were not prolific. One of the last female animals, for instance, when paired with its own uncle, *known to be fertile with sows of a different breed,* produced a litter of 6 and a second litter of 5 weakly piglings; but when Nathusius paired the same sow with a boar of a small black breed, which boar had begotten 7 to 9 young when paired with sows of his own breed (the black breed evidently near homozygous through close breeding), the sow of the large Yorkshire breed produced in the first litter 21 and in the second 18 piglings."

VALUE OF HETEROZYGOSIS IN EVOLUTION.

Before undertaking to discuss the part that heterozygosis may have played in evolution, emphasis must be laid upon one point of criticism directed against almost all speculative evolutionary philosophy. Unconsciously, perhaps, many of the conditions that are widespread among living forms have been spoken of as having been selected to continue their existence in nature because they are indispensable to the organism. This is certainly untrue. One has only to recall other epochs of geology to appreciate the fact. The huge reptiles of the Cretaceous period were long in developing their peculiar specializations, yet they were swept away. In a present-day post-mortem we can assign many reasons why they were eliminated from the organic world, but if their characters were so unfit for their environment, how did they come to be developed? It is said the environment changed and left them too specialized for adaptive response. This is plausible enough, but, nevertheless, possibly untrue.

Must we not be just as skeptical about the question of sexual differentiation? It has arisen several times; it has persisted. Having arisen, it undoubtedly has a function. Perhaps it was necessary; perhaps it was a fundamental blunder, as was once humorously stated. Speculation is, of course, futile. We merely wish to point out that in discussing a function intimately connected with sexual reproduction it is absolutely unnecessary to suppose that sex fulfills a protoplasmic necessity or demand.[1] We do not say that the belief is untrue, but that it is not known to be true and therefore should not be treated as a fact.

In other words, electric drills and hammers are very useful in building a bridge, but good bridges have been built without them. Sexual reproduction serves a purpose, but several of the most vigorous genera of our higher plants have given it up. It is evidently unnecessary to them. We must cast a vote, therefore, against the belief in the rejuvenescence theory of sexual reproduction. Furthermore, we believe that any hypothesis in which an endeavor is made to twist the phenomena attending sexual reproduction into requisites indispensable to the evolution of all species possessing it is without basis. All one can do is to suggest how it may have been beneficial at times to some species.

Transmissible variations are produced in great numbers by apogamous genera such as Taraxacum and Hieracium, so that sexual reproduction is not the cause of variation. Johannsen's (1906) and many other pedigree-culture studies have shown that it presumably never increases variation. But it does permit recombination of the gametic factors of the parents, and this has no doubt been of great service in evolution. Galton and Quetelet (Weismann, 1904) have argued that the intercrossing thus allowed is a means of keeping the species constant, but even with the old idea of blended inheritance this seems to us to be an exaggeration. Greatest constancy in the actual descendants, if new heritable variations are disregarded, would come from asexual reproduction. If the species group is considered as a whole and comparatively free from competition, a great amount of intercrossing—as in a naturally cross-fertilized strain—would help toward a general fixation of type, even though it did not contribute toward the production of homozygous factors; but if a rigid competition is allowed, new and better combinations of characters would replace the old. Perhaps this matter may be made clearer by an illustration drawn from our maize studies. Height is a complex due to many contributing factors. Some of them are probably correlated in inheritance, but a sufficient number are transmitted independently to give the example validity. There is no dominance, and when two individuals differing in stature are crossed there is a blend in the first hybrid generation. There is a real segregation, however, resulting in an increased variability in the F_2 generation. In the F_1 generation there is a normal frequency deviation due to noninherited fluctuations. In the F_2 generation there is a similar curve, but with greater variability, due to fluctuating variability plus the variability due to the recombination of gametic factors. This condition of affairs tends toward the maintenance of a general mean in height, but this mean is false. It is false because the modal class which Galton and Quetelet took to be the type toward which the species is tending actually contains more heterozygous individuals and individuals heterozygous for more factors than any other. An individual selected from this class is less likely to breed true than one selected from the extremes. Cross-fertilization, therefore, may tend toward the production of a mean that gives falsely an appearance of fixity of type.

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[1] Vitalistic interpretations of the origin of characters, though largely confessions of ignorance of ultimate causes, deserve consideration for calling attention to that fact; yet one must admit that if everything is accounted for by some "perfecting principle" this creative force has made many trials and errors. Of course things do not just happen. The chemist sees certain series of compounds give similar reactions under like conditions, while other series give other reactions under those conditions. More complex chemicals under the general term protoplasm probably act in the same manner and produce variations through their reactions. Some of these variations are widespread—that is, they are general reactions; others are less general—that is, they are specific reactions. Personally this analogy helps in the conception of certain orthogenetic phenomena, but the conception leads back to the same blank wall of ignorance. The vitalist and the believer in mechanico-chemical theories reach the same point, but the latter is pleased if he is able to reduce a series of facts to the shorthand of a formula; the former is worried because knowledge stops at the most interesting place.

This preliminary discussion has necessarily been rather long in order to have a basis for considering the part that heterozygosis may have played in evolution. We shall confine ourselves to the higher plants, although we think a portion of the statements made are equally true when applied to animals. It can hardly be doubted that heterozygosis did aid in the development of the mechanisms whereby flowers are cross-fertilized. Variations must have appeared that favored cross-fertilization. These plants producing a cross-fertilized progeny would have had more vigor than the self-fertilized relatives. The crossing mechanism could then have become homozygous and fixed, while the advantage due to cross-fertilization continued. But was this new mechanism an advantage? It must have been often an advantage to the species as a whole. In competition with other species, the general vigor of those which were cross-fertilized would aid in their survival. But the mechanism may not have been useful in evolving real vigor in the species, because of the survival of weak strains in combination. In self-fertilized species, new characters that weakened the individual would have been immediately eliminated. Only strains that stood by themselves, that survived on their own merits, would have been retained. On the other hand, weak genotypes in cross-fertilized species were retained through the vigor that they exhibited when crossed with other genotypes. The result is, therefore, that self-fertilized strains that have survived competition are inherently stronger than cross-fertilized strains. On this account weak genotypes may often be isolated from a cross-fertilized species that as a whole is strong and hardy.

VALUE OF HETEROZYGOSIS IN PLANT BREEDING.

First-generation hybrids of many economic plants give a yield sufficiently greater than pure strains to pay for their production and leave a profit. This is true only of crops where crossing is easy and where profit is made from accelerated and increased cell division or number of fruits. In general, it is not true where the selling price is greatly increased by the possession of some special quality. As Collins has remarked, value may at times accrue also from the fact that a plant breeder who has found a great increase in yield from growing the first hybrid generation of a particular cross may keep the parents a secret and maintain a justly remunerative business by selling hybridized seed or seedlings. A few suggestions as to the crops to which this method may be applied are given below.

MAIZE.

Maize is our most important field crop, and an increase of one bushel per acre to the average yield would add many millions of dollars annually to the nation's resources. The methods now in general use for its improvement all follow Vilmorin's isolation principle. Progeny-row tests are grown from individual ears. This means that good strains are isolated, but it also means that the longer selection is carried on the nearer is a homozygous condition approached. Thus the increased stimulus due to heterozygosis is lost. Since from both Shull's tests and our own, strains made almost homozygous by artificial inbreeding have yielded as high as 250 per cent increase over the average of the parents, this stimulus is not to be lightly disregarded. Of course these tests were made with strains so nearly homozygous that they gave very low yields. But we have obtained yields of ear corn very much higher than are ever given on land of like fertility by commercial types. Shull (1909) has therefore suggested that near-homozygous strains be produced by self-fertilization, the best combination determined by experiment, and hybridized seed of this combination sold. This procedure is undoubtedly the best in theory, because the greatest degree of heterozygosis is thereby obtained. Perhaps it can be made practical, but we are afraid very few commercial men would undertake it.

As a method whose practicability outweighs its theoretical disadvantage, the senior writer (East, 1909) has suggested that combinations of commercial varieties be made, testing them until the most profitable combination is found. Since maize is monœcious, this method can be used on a large scale at a small cost. It is only necessary to take two varieties, *A* and *B*, plant them in alternate rows, and detassel all of the plants of one variety. The seed gathered from this detasseled variety is all crossed seed and will give, in general, a greater yield than the average of the two parents. Crossed seed can be produced in this manner at an additional cost over natural seed of not over 9 cents per bushel. If it averages two bushels per acre increase in yield, the producer can sell it at one dollar advance over natural seed and still allow the buyer a good profit. The method is given in greater detail in another paper (Hayes and East, 1911).

This plan we thought original, but Collins (1910) has shown that it is comparatively old. It has been suggested time and again without gaining a foothold in agricultural practice. Let us hope that the time is now ripe for a scientific method to be understood, appreciated, and used.

It is fortunate that we have at hand data from many agriculturists showing the value of using first-generation hybrids in maize. They are very convincing. We will not discuss them in detail, but refer the reader to Collins's paper (1910). We may say, however, that the following researches have shown that a commercial use of the method is possible: Beal at the Michigan Experiment Station in 1880, Ingersoll at the Indiana Experiment Station in 1881, Sanborn at the Maine Experiment Station in 1889, Morrow and Gardner at the Illinois Experiment Station in 1892, Shull of the Carnegie Institution Station for Experimental Evolution in 1909, East at the Connecticut Experiment Station in 1909, Collins and his assistants of the United States Department of Agriculture in 1910, Hayes and East at the Connecticut Experiment Station in 1911, and Hartley and his assistants of the United States Department of Agriculture in 1912.

TRUCK CROPS.

In some truck and garden crops, such as beans and peas, the difficulty of making artificial crosses absolutely precludes a commercial use of the stimulus due to heterozygosis. Other crops, such as pumpkins and squashes, are too plentiful and cheap to be worth the trouble. Besides, these crops are so often crossed naturally that they are always more or less heterozygous. On the other hand, there are garden crops that are in demand at all seasons of the year and are grown under glass during the winter with profit. Some of them are easily crossed and will pay for their crossing. As examples, tomatoes and eggplants may be cited. Both are easily crossed and are worth crossing. We grew a cross between Golden Queen and Sutton's Best of All tomatoes in 1909. It outyielded both parents. Further, we are informed that several unpublished experiments at the New York Experiment Station by Wellington have shown that crossed seed is worth its production.

Eggplants have another advantage that should be mentioned. Varieties exist whose fruits are so large that the buyer does not care for them, the seller makes no profit, and the plant produces a very limited number. Other varieties have very small fruit. Now fruit size is intermediate in the first hybrid generation, while the number produced is increased and the time of ripening advanced.

PLANTS REPRODUCED ASEXUALLY.

The one type of plants where heterozygosis has been utilized, though not purposely, is that class which is reproduced asexually by cuttings, grafts, etc. Potatoes and grapes are good examples. Commercial varieties are always hybrids, and the reason, we think, is because the hybrids yield so profusely. The cross is made and the best plant of the first generation is simply multiplied indefinitely by division. This method could be applied more generally to bush fruits, such as gooseberries, raspberries, blackberries, etc., and to the larger fruits, like apples, pears, and peaches.

FORESTRY.

There is one other class of economic plants where it seems possible to make a practical use of heterozygosis. We refer to trees used for lumber. Many plans for breeding forest trees have been suggested, yet we have never seen the use of first-generation hybrids suggested. This omission seems strange, for as early as 1855 (Darwin, "Animals and Plants," vol. 2, p. 107) M. Klotzsch crossed *Pinus sylvestris* and *nigricans*, *Quercus robur* and *pedunculata*, *Alnus glutinosa* and *incana*, *Ulmus campestris* and *effusa* and planted the crossed seeds and seeds of the pure parent species in the same place and at the same time. The result was that after eight years the hybrids averaged one-third taller than the parent trees. Further, the quick-growing hybrid walnuts produced by Luther Burbank undoubtedly owe that valuable quality to heterozygosis.

A large amount of experimental work will be necessary before definite recommendations can be made as to what species can be crossed, what result may be expected, and what extra cost must be allowed for the production of hybrid seed. It is perfectly evident that hybrid seed will be impossible in many cases, and even where hybrids can be produced comparatively few can be crossed at a small enough cost to make the scheme a commercial success. On the other hand, we have no doubt that with many good lumber trees crossing would be found easy and hybrid seed could be sold with a wide margin of profit both to producer and to forester.

BIBLIOGRAPHY.

The following is a complete list of the literature cited in this bulletin:

Barber, M. A. On heredity in certain micro-organisms. Kansas University Science Bulletin 1, vol. 4, 1907, pp. 1–48.

Baur, E. Das Wesen und die Erblichkeitsverhältnisse der "Varietates albomarginatae hort." von Pelargonium zonale. Zeitschrift für Induktive Abstammungs- und Vererbungslehre, vol. 1, 1909, pp. 330–351.

Berthollet, Sabine. Phénomènes de l'acte mystérieux de la fécondation. Mémoires de la Société Linnéenne de Paris, vol. 5, 1827, pp. 81–83.

Blyth, E. On the physiological distinctions between man and all other animals. Magazine of Natural History, n. s., vol. 1, 1837, pp. 1–9, 77–85, 131–141.

Castle, W. E. A Mendelian view of sex heredity. Science, n. s., vol. 29, 1909, pp. 395–400.

——— Heredity in relation to evolution and animal breeding, New York, 1911; 184 pp., illustrated.

——— and **Little**, C. C. On a modified Mendelian ratio among yellow mice. Science, n. s., vol. 32, 1910, pp. 868–870.

——— **Carpenter**, F. W., et al. The effects of inbreeding, crossbreeding, and selection upon the fertility and variability of Drosophila. Proceedings of the American Academy of Arts and Sciences, vol. 41, 1906, pp. 731–786.

Collins, G. N. The value of first-generation hybrids in corn. Bulletin 191, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910, 45 pp.

Crampe, H. Zucht-Versuche mit zahmen Wanderratten. Landwirthschaftliche Jahrbucher, vol. 12, 1883, pp. 389–458.

Darwin, Charles. The variation of animals and plants under domestication (2d edition), London, 1875, 2 vols., illustrated.

——— The effects of cross and self fertilisation in the vegetable kingdom. London, 1876, 482 pp.

De Vries, H. Plant breeding, Chicago, 1907, 360 pp.

East, E. M. The relation of certain biological principles to plant breeding. Bulletin 158, Connecticut Agricultural Experiment Station, 1907, 93 pp.

——— Inbreeding in corn. Report, Connecticut Agricultural Experiment Station, 1907, pp. 419–428. (1908.)

——— The distinction between development and heredity in inbreeding. American Naturalist, vol. 43, 1909, pp. 173–181.

——— The rôle of hybridization in plant breeding. Popular Science Monthly, vol. 77, 1910, pp. 342–355.

——— The transmission of variations in the potato in asexual reproduction. Report, Connecticut Agricultural Experiment Station, 1909–10, pp. 120–160. (1910a.)

——— The genotype hypothesis and hybridization. American Naturalist, vol. 45, 1911, pp. 160–174.

——— and **Hayes**, H. K. Inheritance in maize. Bulletin 167, Connecticut Experiment Agricultural Station, 1911, 141 pp., 25 pls. (1911a.)

Emerson, R. A. Inheritance of sizes and shapes in plants. Preliminary note. American Naturalist, vol. 44, 1910, pp. 739–746.

Fabre-Domengue, P. Unions consanguines chez les Columbins. L'Intermédiare des Biologistes, vol. 1, 1898, pp. 203.

Focke, W. O. Die Pflanzen-Mischlinge, Berlin, 1881, 569 pp.

Gärtner, C. F. Versuche und Beobachtungen über die Bastarderzeugung im Pflanzenreich, Stuttgart, 1849, 790 pp.

Guaita, G. von. Versuche mit Kreuzungen von verschiedenen Rassen der Hausmaus. Berichte der Naturforschenden Gesellschaft zu Freiburg, vol. 10, 1898, pp. 317–332.

Hanel, E. Vererbung bei ungeschlechtlicher Fortpflanzung von Hydra grisea. Jenaische Zeitschrift für Naturwissenschaft, vol. 43, 1907, pp. 321–372.

Harris, J. A. The biometric proof of the pure line theory. American Naturalist, vol. 45, 1911, pp. 346–363.

Hayes, H. K., and East, E. M. Improvement in corn. Bulletin 168, Connecticut Agricultural Experiment Station, 1911, 21 pp.

Herbert, W. Amaryllidaceæ, London, 1837, 428 pp.

Jennings, H. S. Heredity, variation and evolution in Protozoa. II. Heredity and variation of size and form in Paramaecium, with studies of growth, environmental action, and selection. Proceedings of the American Philosophical Society, vol. 47, 1908, pp. 393–546.

——— Experimental evidence on the effectiveness of selection. American Naturalist, vol. 44, 1910, pp. 136–145.

Jensen, P. Organische Zweckmässigkeit, Entwicklung und Vererbung vom Standpunkt der Physiologie, Jena, 1907.

Johannsen, W. Ueber Erblichkeit in Populationen und in reinen Linien, Jena, 1903, 68 pp.

——— Does hybridization increase fluctuating variability? Report of the Third International Conference on Genetics, London, 1906, pp. 98–113.

——— Elemente der exakten Erblichkeitslehre, Jena, 1909, 515 pp.

——— The genotype conception of heredity. American Naturalist, vol. 45, 1911, pp. 129–159.

Jost, L. Lectures on plant physiology. (English translation by R. J. H. Gibson.) Oxford, 1907, 564 pp.

Keeble, F., and Pellew, C. The mode of inheritance of stature and of time of flowering in peas (*Pisum sativum*). Journal of Genetics, vol. 1, 1910, pp. 47–56.

Knight, T. A. Philosophical transactions. See Knight's collected works, London, (1799) 1841.

Knuth, P. Handbuch der Blütenbiologie, Leipzig, 1898–1905, 3 vols.

——— Handbook of flower pollination. (Translated by J. R. Ainsworth Davis.) Oxford, 1906–1909, 3 vols.

Kölreuter, J. G. Dritte Fortsetzung der vorläufigen Nachricht von einigen das Geschlecht der Pflanzen betreffenden Versuchen und Beobachtungen, Leipzig, 1766, 156 pp. (Reprinted in Ostwald's Klassiker der exakten Wissenschaften, no. 41, Leipzig, 1893).

Lang, A. Die Erblichkeitsverhältnisse der Ohrenlänge der Kaninchen nach Castle und das Problem der intermediären Vererbung und Bildung konstanter Bastardrassen. Zeitschrift für Induktive Abstammungs- und Vererbungslehre, vol. 4, 1911, pp. 1–23.

Lecoq, H. De la fécondation naturelle et artificielle des végétaux et de l'hybridation, Paris, 1845, 287 pp.

Love, H. H. Are fluctuations inherited? American Naturalist, vol. 44, 1910, pp. 412–423.

Mauz, E. In Correspondenzblatt des Württemburgischen Landwirthschaftlichen Vereins, 1825.

MÜLLER, H. Die Befruchtung der Blumen durch Insekten und die gegenseitigen Anpassungen beider, Leipzig, 1873, 478 pp.

NILSSON-EHLE, H. Kreuzungsuntersuchungen an Hafer und Weizen. Lunds Universitets Årsskrift, n. s., sec. 2, vol. 5, no. 2, 1909, 122 pp.

PEARL, R. Inheritance of fecundity in the domestic fowl. American Naturalist, vol. 45, 1911, pp. 321–345.

——— and SURFACE, F. M. Is there a cumulative effect of selection? Zeitschrift für Induktive Abstammungs- und Vererbungslehre, vol. 2, 1909, pp. 257–275.

——— ——— Data on the inheritance of fecundity obtained from the records of egg production of the daughters of "200-egg" hens. Bulletin 166, Maine Agricultural Experiment Station, 1909, pp. 50–84.

PEARSON, K. Darwinism, biometry, and some recent biology, I. Biometrika, vol. 7, 1910, pp. 368–385.

RITZEMA BOS, J. Untersuchungen über die Folgen der Zucht in engster Blutverwandtschaft. Biologisches Centralblatt, vol. 14, 1894, pp. 75–81.

SAGERET, A. Considérations sur la production des hybrides, des variantes et des variétés en général, et sur selles de la famille de Cucurbitacées en particulier. Annales des Sciences Naturelles, vol. 8, 1826, pp. 294–314.

SHULL, G. H. The composition of a field of maize. Report, American Breeders Association, vol. 4, 1908, pp. 296–301.

——— Hybridization methods in corn breeding. American Breeders Magazine, vol. 1, 1910, pp. 98–107.

——— The genotypes of maize. American Naturalist, vol. 45, 1911, pp. 234–252.

TAMMES, T. Das Verhalten fluktuierend variierender Merkmale bei der Bastardierung. Recueil des Travaux Botaniques Néerlandais, vol. 8, 1911, pp. 201–288.

WEISMANN, A. The evolution theory. (Translated by J. A. Thomson and M. R. Thomson.) London, 1904, 2 vols.

WIEGMANN, A. F. Ueber de Bastarderzeugung im Pflanzenreich, Braunschweig, 1828, 40 pp.

WOODRUFF, L. L., and BAITSELL, G. A. The reproduction of Paramaecium aurelia in a "constant" culture medium of beef extract. Journal of Experimental Zoology, vol. 11, 1911, pp. 135–142.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 244.

B. T. GALLOWAY, *Chief of Bureau.*

THE EXPORT AND MANUFACTURING TOBACCOS OF THE UNITED STATES, WITH BRIEF REFERENCE TO THE CIGAR TYPES.

BY

E. H. MATHEWSON,
Crop Technologist, Office of Tobacco Investigations.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C, February 16, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "The Export and Manufacturing Tobaccos of the United States, with Brief Reference to the Cigar Types," by Mr. E. H. Mathewson, Crop Technologist in the Office of Tobacco Investigations, and recommend that it be published as Bulletin 244 of the series of this Bureau.

The manuscript was prepared in response to a long-felt need for a general study of the tobacco-growing industry as a whole, so that the various types of tobacco produced in the United States may be understood in proper relation to each other and to the tobacco trade as a whole.

The accompanying maps, indicating the location of the different tobacco districts, are regarded as a particularly valuable feature of the bulletin, and it is in response to a specific demand for such maps from the trade as a whole that they have been prepared for publication.

Respectfully,
B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—727.

THE EXPORT AND MANUFACTURING TOBACCOS OF THE UNITED STATES, WITH BRIEF REFERENCE TO THE CIGAR TYPES.

INTRODUCTION.

DISTINCTION BETWEEN THE EXPORT AND MANUFACTURING AND THE CIGAR TYPES OF TOBACCO.

The designations "export" and "manufacturing" are used by the trade to distinguish these tobaccos from cigar tobacco. The terms themselves do not make the distinction very clear. The making of cigars might, of course, be regarded as a manufacturing process, but as here used the term is limited to the domestic manufacture of pipe and cigarette smoking tobacco, cigarettes, chewing tobacco, and snuff. There is, however, some reason for restricting the term "manufacturing" to these types, because the making of cigars is largely a hand process, requiring in its simpler forms no machinery worth mentioning. In the case of the manufacturing tobaccos, however, the machinery used is the dominating element, from putting the leaf into keeping order by the elaborate and costly machine drier to the finished products of the plug presses, the granulating and cutting machines, and the snuff and cigarette machines. The manufacture of these types adapts itself readily to the concentration of a great business into a single very large factory, with an elaborate and costly machine equipment, without which the chances of successful competition are minimized. As is well known, this point has been of fundamental importance in the success of the great tobacco combinations in the manufacturing field.

The export tobaccos are of the same general type as those used in domestic manufacture, the same general methods are used in producing and handling them, and in finding a market they move through the same channels of trade. The export and manufacturing tobaccos are thus naturally and properly considered together as a single broad type, although, as will be explained later, there are important modifications of quality in connection with some of them that cause certain types to be used mostly for domestic manufacture and consumption and others to be mainly exported.

We have already noted one important difference between the cigar and the export and manufacturing tobacco industries; that is, in the machinery used in manufacture and in the tendency to consolidation in large plants. This, however, is only one of several reasons that cause them to fall quite naturally into different classifications.

The cigar tobaccos are produced on different soils and in other sections of the country. A very different type of seed is used. The methods of cultivation, harvesting, and especially handling after harvest are distinctive, and they move to market through separate trade channels. The Bureau of Internal Revenue expressly forbids the making of cigars and the manufacture of tobacco in the same factory, and with some exceptions the growers, handlers, dealers, and manufacturers of the export and manufacturing tobaccos generally have very little or nothing to do with cigar tobacco.

IMPORTS AND EXPORTS OF TOBACCO.

The standard of quality in the export and manufacturing and in the cigar types of tobacco is very different, which is strikingly emphasized by the fact that while some thirty-odd millions of pounds of cigar tobacco are imported yearly, above 300,000,000 pounds of the other type (average of 1910 and 1911 was 356,261,573 pounds) are each year exported. Strangely enough, however, the value per pound of the tobacco imported is so much greater than of that exported that the value of the imports offsets about two-thirds the value of our exports (for 15 years ending with 1911, 61 per cent; for the fiscal year 1910–11, 72 per cent), so that the balance of trade in favor of the United States on the tobacco account is smaller than might be supposed.

The tobacco which is imported consists principally of cigar-filler leaf and cigars from Cuba and cigar-wrapper leaf from the Dutch East Indies (Sumatra and Borneo, purchased at Amsterdam and Rotterdam, Holland) and is the finest and highest-priced tobacco in the world. Our imports of Turkish tobacco, for use principally in cigarettes, is coming to be of considerable importance and is rapidly increasing.

This imported tobacco bears a very high rate of import duty for the protection of cigar-leaf growers in the United States and for revenue, which is at the rate of $1.85 per pound on wrappers and 35 cents per pound for fillers, with a reciprocity discount of 20 per cent in the case of Cuban imports. Adding this duty to the declared value of the imported tobacco and cigars causes it to exceed the value of our exports by more than 30 per cent. These values are shown in Tables I and II.

TABLE I.—*Exports of tobacco produced in the United States for the fiscal year ended June 30, 1908.*

Kinds.	Pounds.	Value.	Kinds.	Number.	Value.
Leaf	323,033,034	$34,342,293	Cigarettes	1,539,364,000	$2,000,881
Stems and trimmings	7,779,624	384,864	All other tobacco		1,158,051
Plug	6,295,757	1,525,888			
Cigars	2,352,000	51,702	Total		39,463,679

TABLE II.—*Imports of tobacco into the United States for consumption in the fiscal year ended June 30, 1908.*

Kinds.	Pounds.	Value.	Duty.	Value (duty added).
Wrapper leaf	5,396,539	$6,073,444.52	$9,949,094.04	$16,022,538.56
Filler leaf	27,183,222	16,166,369.02	8,513,519.16	24,679,888.18
All other leaf	89,488	35,470.30	42,068.54	77,538.84
Stems	3,164,242	15,280.00		15,280.00
Cigars and cheroots	704,875	4,011,177.80	3,342,527.13	7,353,704.93
Cigarettes	22,452	69,081.87	115,969.28	185,051.15
Other manufactured tobacco	358,841	139,699.80	196,911.59	336,611.39
Total		26,510,523.31	22,160,089.74	48,670,613.05

The trade movements of the export and manufacturing types are of course not entirely separate from the cigar types, and one could easily find points of real contact and more or less striking points of similarity. There are no official figures to quote, but it is generally known by those connected with the trade that every year some of the export types of tobacco are used in the manufacture of cheap cigars, stogies, and cheroots. Conversely, a considerable quantity of cigar leaf in the aggregate is used in manufactured tobacco, particularly in those brands known as scrap tobacco, made largely from cigar cuttings and the heavier and commoner grades of cigar leaf. As noted in Table I, also, more than 2,000,000 cigars are exported annually, which is an insignificant quantity compared with our imports or home consumption, and it is generally known that a small quantity of cigar leaf is exported annually, notably to Canada, England, and Germany.

Imports include also a very small quantity of manufactured tobacco, mostly fancy brands used by foreigners resident here; some cigarettes, mostly of Turkish tobacco; and a considerable and rapidly increasing quantity of Turkish leaf now amounting to about 10,000,000 pounds annually for use in manufacturing Turkish cigarettes and for blending with our own domestic cigarette and smoking-tobacco mixtures.

EARLY HISTORY OF THE TOBACCO INDUSTRY.

DEVELOPMENT IN COLONIAL TIMES.

The commercial culture of tobacco in this country was almost coincident with the first permanent settlement established at Jamestown, Va., in 1607. The people of Great Britain and of Continental Europe had already become familiar with the use of tobacco from the numerous expeditions to various parts of the New World during the previous 115 years since its discovery by Columbus, and during the last 50 years of that period it had become common to include as much tobacco as possible in the return cargo from the various parts of the New World where it might be obtained from the natives. Introduced first because of its supposed medicinal effects, the taste and demand for it had already become general in much of Europe and the British Isles.

The Virginia colonists soon found that it was about the only commodity which they could produce that would exchange to advantage against the various manufactured necessities or luxuries which they desired from the home country. History records that John Rolfe was growing tobacco in the streets of Jamestown in 1612, and in 1618 the first official statement of exports is recorded, which amounted in that year to 20.000 pounds of tobacco at a valuation of 54¾ cents per pound.

These early settlers found a heavily forested country, which required a great expenditure of labor to clear and put into shape for planting. Nothing else that could be grown would produce so large an exchange value from a given area of land against manufactured commodities from home as tobacco. It absorbed almost the entire attention of the early settlers, aside from producing sufficient corn, wheat, and vegetables for mere subsistence. At first the cultivation was restricted almost entirely to the richest river land along the James, the York, and the Rappahannock Rivers, where the largest yield and highest return for a given amount of effort could be obtained

New colonists were constantly arriving and the production of tobacco increased with wonderful rapidity. From 20,000 pounds in 1618 the exports increased in 1627, nine years later, to 500,000 pounds.

In the later forties the palatinate of Maryland (officially established in 1634 with the first settlement at St. Marys) was also developing rapidly in population and in the production of tobacco, which became there also the main reliance and most available resource as a commercial medium for exchange against the necessities and luxuries of the Old World.

In 1639 the total exports for the two colonies reached the large total of 1,500,000 pounds, but the value had dropped to 6.08 cents a pound.

Although the market in England and on the Continent was a rapidly expanding one, production in America under the influence of necessity occasioned by the rapidly increasing influx of immigration, particularly indentured white laborers and negro slaves, increased at a still greater rate. Just at this period also, England was entering upon her navigation and colonial policy, which had for its object the building up of English shipping, creating and retaining exclusive control of the colonial markets for home manufactures and increasing national resources.

Parliament passed laws effectively prohibiting the importation of any tobacco except from the Colonies. This excluded Spanish colonial tobacco, which had hitherto been of considerable importance, and secured a monopoly of the British markets for the Colonies. Conversely, however, the Colonies were forbidden to export tobacco, except to the mother country and in English ships. This had the effect of reserving the market for colonial tobacco to England only and helped to build up English shipping, but it placed the colonists entirely at the mercy of English merchants and shipowners as to prices obtained for tobacco. The British merchants, however, could sell colonial tobacco to other countries freely after it had passed the British ports, and it is estimated that during the colonial period two-thirds or more of the colonial tobacco reaching England was resold for use in continental countries. England thus became the great supply center for leaf tobacco for the rest of Europe.

In order to increase colonial imports, augment customs receipts, and make the farming out of the tobacco monopoly of greater value to the King, the growing of tobacco in Britain, which had already become of some importance in certain sections there, was forbidden. Laws were also passed discouraging the development of any manufacturing activities in the Colonies in order to retain the colonial markets for British products. This, too, had the effect of making still more complete the dependence of the Colonies upon agriculture alone as a means of livelihood, and for exchange purposes tobacco seemed to be the only resource. The whole policy as outlined, together with the rapidly increasing population of the Colonies, conspired to increase production and depress prices.[1]

In 1664 exports amounted to 23,750,000 pounds at 3.09 cents a pound. So it went on with production and prices fluctuating greatly from year to year throughout the whole colonial period, the production always tending to expand rapidly, as the average of a series of years, attended with chronic dissatisfaction from low prices. The lowest recorded price was 1.52 cents a pound in 1730, when exportations were 36,000,000 pounds.

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[1] It should perhaps be noted in this connection that the action of this colonial policy in respect to Maryland was somewhat different from that of the other colonies. Maryland was a palatinate and as such had a degree of freedom from control by the mother country not enjoyed by Virginia and the other Colonies. For example, the policy limiting the exports of colonial tobacco to Great Britain did not apply to Maryland. She thus enjoyed a freer market and sold much of her product directly to other countries in Europe, particularly to France and Holland, and built up a trade in tobacco leaf with these countries which has persisted. These countries continue to take between them the larger portion of the Maryland product. Virginia, however, produced a much larger quantity of tobacco than Maryland, and was really the controlling factor in prices and production in colonial times.

All through this early period tobacco was a constant source of legislation, particularly in the Virginia Assembly, in the effort to control production and keep up the price, but the effort usually met with little or at best only temporary success. Laws limiting the number of plants grown by each planter, limiting the number of leaves to be harvested, providing for the total destruction of a portion of the stocks on hand, or eliminating a crop altogether were passed from time to time. On several occasions memorials were addressed to the King praying for relief. Several times negotiations between Virginia and Maryland were attempted for the purposes of limiting production and maintaining prices, but it usually happened that lack of unity would defeat the effort, and when one colony tried to limit production, the other would increase the acreage. Warehouses, or rolling houses as they were first called, were established at several points with sworn official inspectors. Laws were passed placing heavy penalties against nesting or false packing, in the hope thus to raise the price level which the English merchants would be willing to pay. Both Maryland and Virginia tried to fix artificially the price of tobacco by statute. No legislative device, however, seemed able permanently to overcome the combined influence of the natural conditions favoring the production of tobacco and the artificial influences of the British colonial policy and navigation laws and the rapidly increasing colonial population, including cheap slave labor in particular.

Production, therefore, continued to increase and low prices worried the colonists until the outbreak of the American Revolution, when the production in the Colonies was at its maximum. Exports averaged about 100,000,000 pounds annually for the years 1770 to 1774. But the war, of course, nearly put a stop to exports. The English market, which had been receiving almost all the colonial tobacco, was closed to the Colonies and the danger from seizure by English privateers and gunboats was great and the war itself absorbed the attention of the great body of the people. The low mark for this period was reached in 1776, when exports were only 2,440,947 pounds of tobacco, and the exports for the seven years of war averaged less than 12,500,000 pounds yearly.[1]

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[1] It may be of interest to note that soon after the establishment of the permanent colonies in the New England section attempts were made there to grow and export tobacco, but conditions were such that these efforts were attended with no real success. The principal cause of this failure in New England was largely due to its soil, which did not possess anything like the natural fertility of the rich river valleys of Virginia. Tobacco growing in New England never amounted to much until the introduction of the cigar-tobacco industry into the Connecticut Valley in the second quarter of the nineteenth century.

At the close of the Revolutionary War the production and exportation of American tobacco was of course resumed, but under very different conditions, as the British colonial policy and navigation laws were no longer effective here.

Almost from the beginning of the commercial trade in tobacco it seems to have been regarded as an available asset for taxation. In Great Britain and in many of the continental countries it was made to yield a good revenue by duties upon imports and by farming out the privilege of trading in it. Indeed, the Colonies themselves were able to realize considerable public revenue by means of an export tax, which stood for a portion of the time in both Virginia and Maryland at 2 shillings per hogshead. This policy of using tobacco as a subject for taxation, as is well known, has become a fixed policy with most of the leading nations to-day, either in the form of customs duties or internal taxes or by governmental monopoly, and the revenue exacted is in many cases much more than the value of the tobacco itself.

DEVELOPMENT FROM THE REVOLUTION TO THE CIVIL WAR.

In the half century succeeding the Revolutionary War a number of effective causes tended to check the production and exportation of leaf tobacco in the United States. The war itself had made it impossible for European countries to import their regular supplies of American tobacco, and they turned to other sources, particularly to Cuba and to the Dutch East Indies. They also tried the experiment of producing a portion of their supply at home. The long series of Napoleonic wars, which for many years absorbed the attention of all Europe and which at times almost prohibited and nearly always menaced commerce seriously, tended still further to encourage home production of tobacco by the countries of Europe.

From the close of our Revolutionary War to the breaking out of the War of 1812 exports of tobacco fluctuated from about 50,000,000 to 100,000,000 pounds a year, with an average of about 75,000,000 pounds, except in the year 1807, when the effect of the Berlin and Milan decrees made all commerce with England or Europe practically impossible and our exports were but 9,576,000 pounds. The War of 1812, with President Jefferson's embargo proclamation forbidding all American ships to leave port, caused our shipments of tobacco in 1812 and 1813 to aggregate only 5,314,000 and 3,125,000 pounds, respectively.

After the world-wide cessation of hostilities in 1815, following Waterloo in Europe and New Orleans in this country, our exports of tobacco again immediately rose to fairly large proportions. All Europe, however, including England, found itself financially prostrated, and tobacco was one of the commodities selected upon which to levy still higher taxes. For example, Great Britain, which had been collecting an import duty of 15 cents per pound on tobacco, raised it in 1815 at one leap to 75 cents per pound. Such a great increase in the tax of course seriously upset and hindered normal trade movements in leaf tobacco for a considerable time, and it was not until 1840 that our exports of leaf really began to average higher than they did just before the Revolutionary War. In 1840 the exports of leaf were 147,828,000 pounds and continued at about this average with a slight tendency to increase until just before the breaking out of the Civil War, the maximum figure up to that time being recorded in 1858, when 204,213,000 pounds of leaf were exported.

The greatly increased economic independence resulting from national independence, with freedom from the repressive navigation laws and colonial policy of Great Britain, had the double effect of increasing interest in manufactures (forbidden by the British colonial policy) and rendering the Colonies less dependent upon a single agricultural product. After the Revolutionary War, therefore, from about 1800 on, the price of tobacco ruled at a considerably higher level than in colonial times. In the colonial period from 3 cents to 4 cents a pound was the rule. From independence to the Civil War the average ranged from 6 cents to 9 cents, and it but once got below 5 cents (4.9 cents in 1842) and on several occasions went above 12 cents a pound.

DEVELOPMENT OF TOBACCO MANUFACTURES.

Our manufactures of tobacco in colonial times were inconsequential and our exports of manufactured tobacco were nothing. We even imported considerable smoking tobacco and snuff from the home country. With independence, however, and freedom from England's oppressive colonial policy, the development of tobacco manufactures in the tobacco-growing States at once became of importance. In 1790, 28,637,175 pounds were manufactured and used in domestic consumption. Exports of manufactured tobacco, however, amounted to only 96,811 pounds, but the growth, though gradual in the early days, was steady and certain. In 1820 the exports of manufactures had grown to 1,377,501 pounds, and in the census year 1859, just before the Civil War, to 17,737,232 pounds, the highest record to the present time.[1]

EXTENSION OF PRODUCING AREAS.

During the colonial period Virginia and Maryland had produced practically all of the tobacco in this country, except a comparatively small quantity from the border counties of North Carolina. With the close of the Revolutionary War the pioneering movement to the country beyond the Alleghenies into what is now Kentucky, Tennessee, and southern and eastern Ohio went on at an increased rate. Many of these frontiersmen were from the tobacco-producing sections of Virginia and Maryland and it was quite natural that they should try tobacco growing in the new settlements. As in Virginia, the soil and other natural conditions of much of this new country were suitable for the production of tobacco. Marketing facilities were available by means of the numerous navigable rivers connecting with the Ohio and Mississippi Rivers and down these to New Orleans and thence to the markets of Europe on nearly as favorable a basis as that enjoyed by Virginia and Maryland.

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[1] Basis of foregoing figures, Yearbook, U. S. Dept. of Agriculture, for 1908, pp. 683-688.

As the population of these States grew, so did the production of tobacco, and by 1840 we find Kentucky producing much more than Maryland, and ranking second only to Virginia until, with the favoring influence of the Civil War, which entirely prostrated production in Virginia, she passed into first place, a position which she continues easily to hold by a big margin.

In this period also the production of tobacco was carried over into Missouri on an extensive commercial scale. The crop in that State amounted in 1860 to 25,086,196 pounds and in 1876 its largest crop was produced, amounting to 43,245,000 pounds, causing it to rank in production for that year ahead of the other important producing States, Tennessee, Ohio, Maryland, and North Carolina, and inferior only to Kentucky and Virginia. Missouri's product has recently fallen off markedly in quantity, however, and she is now no longer to be reckoned among the important tobacco-growing States.

BEGINNINGS OF THE CIGAR-TOBACCO INDUSTRY.

During the colonial period the production of distinctive cigar types of tobacco was not recognized, and there had been no important commercial development of tobacco growing in any of the now important cigar-tobacco producing sections of our country.

During the first quarter of the nineteenth century the manufacture of cigars had its infant beginnings as a household industry in some of the Connecticut Valley country towns. The industry grew very slowly at first and correspondingly slow progress was made in the growing of cigar leaf, which likewise had its beginnings in the Connecticut Valley in the section between Hartford, Conn., and Springfield, Mass.

Other centers of development for the production of the cigar or seed-leaf types of tobacco almost coeval with that of the Connecticut Valley were the present area in Lancaster and York Counties, Pa.; the Gadsden County, Fla., area; the Miami Valley, Ohio, area; and the Onondaga and Big Flats areas in New York State. In none of these areas, however, did the production of cigar tobacco attain much importance till the closing decade of the period just preceding the Civil War. This fact is shown in Table III.

Table III.—*Development of cigar-tobacco production in the decade preceding the Civil War.*

Localities.	1849	1859
Connecticut Valley:	*Pounds.*	*Pounds.*
Connecticut	1,267,624	6,000,133
Massachusetts	138,246	3,233,198
Total for Connecticut Valley	1,405,870	9,233.331
Pennsylvania	912,651	3,181,586
Ohio, Miami Valley [1]	1,200,000	3.900.000
Florida	998,000	828.815
New York [2]	500,000	1,500.000
Total cigar leaf	5,016,521	18,643.732

[1] Figures for 1852, 4,000 cases; for 1860, 13,000 cases (from Killebrew's Tenth Census report). Weight of cases estimated at 300 pounds each by the writer.
[2] Approximation from estimates in Killebrew's Tenth Census report.

The present important Wisconsin area had no development of commercial importance until after the Civil War.

This rapid increase in the production of cigar-leaf tobacco during the decade 1850 to 1860 was coincident with a rapid development in the use of cigars in this country. This development was likewise reflected in our imports of cigars and cigar leaf for the same period. The number of cigars imported in 1850 was 124,303,000, valued at $1,469,097, which was increased in 1860 to 460,404,000, valued at $4,581,551. Imports of unmanufactured tobacco (practically all cigar leaf) likewise increased from 2,480,446 pounds (valued at $272,438) in 1850, to 6,940,671 pounds (valued at $1,365,695) in 1860. The larger part of the leaf imported was from Cuba and the cigars were principally from Cuba and Germany. The high-grade cigars came from Cuba and the lower grade, representing the bulk of the imports, came mostly from Germany.[1]

SUMMARY (REVOLUTION TO THE CIVIL WAR PERIOD).

In this brief account of the development of the tobacco industry in the United States from the period of our Revolution to that of the Civil War, the important influence of national independence with consequent economic freedom from the British colonial and navigation policy has been noted. Dependence upon tobacco as practically the sole medium of exchange against manufactured necessities became less urgent because many of the people could turn their attention to the pursuits of manufacturing, including the manufacture of tobacco itself, both for home use and for a slowly expanding export trade.

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[1] Dodge's Tenth Census report, p. 48.

The long series of wars involving all Europe, including our own War of 1812, greatly retarded international trade in tobacco as well as in other commodities and, together with the generally high revenue tariffs levied on tobacco in the period succeeding these wars, which had exhausted all the leading nations financially, still further retarded the development of our exports of tobacco and encouraged the home production of leaf on the part of many of the leading nations of continental Europe. It was not until about 1845 that our exports of tobacco began to expand much above the volume reached in the years just preceding the Revolution.

The rapid settlement of Kentucky and border areas in Ohio, Indiana, Missouri, and Tennessee, largely by pioneers from Virginia, Maryland, and North Carolina, rapidly extended the production of tobacco into this new territory so that at the breaking out of the Civil War the annual production of tobacco in this new territory across the Alleghenies was nearly equal to that in the older area, with Kentucky second only to Virginia in production, and Tennessee ranking third, her production being slightly ahead of either Maryland or North Carolina.

The manufacture and use of cigars and the home production of cigar tobacco were having their early struggles for development in the second quarter of the nineteenth century, ending in a period of very rapid development from 1850 to 1860. This development was accompanied by a rapid rise in the importation of cigars and cigar leaf, so that by 1860 the cigar-tobacco trade and the production of cigar leaf had become really an important feature in the tobacco industry.

DEVELOPMENT DURING THE PERIOD SINCE THE CIVIL WAR.

INFLUENCE OF THE WAR.

As in the case of the Revolutionary War, the Civil War and the developments growing out of it exercised most important influences on the tobacco industry in all its phases. Virginia itself, which up to this time was the most important producing area and really dominated the tobacco trade, became the actual battle field of the great struggle which completely absorbed the activities of her people. The cultivation, exportation, and manufacture of tobacco within her borders became greatly disorganized and its cultivation there was almost completely abandoned. The total production of the country, which in 1859 was 434,209,461 pounds, was in 1863 only 163,353,082 pounds. The value per pound, however, was 14.8 cents, a higher figure than had been recorded since 1816, immediately succeeding the War of 1812, and higher than any yearly average figure which has been recorded since the Civil War. The exports of manufactured tobacco decreased from 17,737,232 pounds in 1859 to 4,110,802 pounds in 1861.

The shrinkage in exports of leaf, however, was comparatively slight because, under the influence of high prices, effort was made to export as much as possible. The conditions in the western producing territory, particularly in Kentucky and Ohio, were not so completely unfavorable for the production of tobacco as in Virginia, Maryland, and North Carolina, and the production in the West remained fairly large during most of the active period of the war. The influence of the Civil War, indeed, brought Kentucky to first place as a producing State, which place she has continued easily to hold.

INFLUENCE OF THE NEW FISCAL SYSTEM.

INTERNAL-REVENUE TAX.

The financial necessities of our National Government brought about by the tremendous expenses of the war led to many new devices for raising revenue. The war-revenue act of 1862 placed an internal-revenue tax on all manufactured tobacco. Up to this time no tax had been levied except for two short periods of trial in 1794, and again during the period of the War of 1812. Since the passage of this law in 1862 tobacco has regularly been one of the principal sources of revenue, although the rate of levy has passed through a great variety of changes.

IMPORT DUTY ON CIGARS AND CIGAR LEAF.

Prior to the Civil War the import duty on cigars and leaf tobacco was comparatively low and was not sufficient materially to affect imports. The revenue act of 1862, however, materially increased these rates and greatly stimulated the home production of cigar-leaf tobacco and the home manufacture of cigars. The revenue rates were still further increased later on, with the effect of greatly reducing the imports of both cigars and leaf tobacco and practically excluding all but the highest grades of cigars and leaf.

The import tax on tobacco has been maintained upon a high basis and the present rates of 35 cents a pound on filler and $1.85 a pound on wrapper leaf are equivalent to about 50 per cent ad valorem on fillers and about 175 per cent on wrappers. It is claimed that the domestic wrapper-producing industry would be ruined with any material reduction of the rate on wrapper leaf. Nevertheless, we continue to import wrappers of the finest grades to the extent of about 6,000,000 pounds annually.

Estimating that 3 pounds of these high-grade wrappers are required to wrap a thousand cigars, the duty amounts to a full half cent for each cigar covered with imported wrappers. The duty on cigars ($4.50 a pound and 25 per cent ad valorem) is much higher and is equivalent to about 6½ cents for each cigar imported. It should be said in this connection, however, that since practically all of the cigars imported are from Cuba, where the reciprocity treaty reducing the statutory figures by 20 per cent is in force, the real tax collected for the larger portion of our imports amounts to about 5 cents for each cigar.

The importation of both cigars and cigar-leaf tobacco received a sharp setback by the raising of the import duties at the time of the Civil War. Because of the demand for the highest grade cigars, the importation of cigar leaf has nevertheless tended since then toward a gradual increase. The official figures show that the average annual importation of cigar leaf was about four times larger in the first decade of the twentieth century than during the few years prior to the Civil War before the tax was increased.

Under the influence of the heavy discriminating duty levied on the manufactured product the number of cigars now imported is still much below the figures set in the last few years preceding the war. The cigars imported in 1860 numbered 460,404,000, as previously stated. These figures[1] were reduced to 26,864,000 in 1868, and in later years, during the period from 1903 to 1908, our importations of cigars have averaged only about 55,000,000 yearly, or about 13 per cent of the high-record figures of 1860. It is unquestionably true, however, that in this country we really smoke more Havana cigars than ever before, as the importation of Havana tobacco has increased sufficiently to much more than offset the decrease in importations of cigars under the influence of the very large discriminating duty on cigars as compared with the raw leaf.

DEVELOPMENT OF CIGAR-LEAF PRODUCTION.

Under the combined influences of a high protective tariff and the rapid increase in popularity of cigar smoking the cultivation of cigar tobacco and the manufacture and sale of cigars have increased enormously, far outstripping the manufacturing types in rate of growth in the period since the Civil War. In 1859 the domestic production of cigar tobacco, as we have seen, was 18,643,732 pounds, and the total production of all types of tobacco in the United States was 434,209,461 pounds. Thus the production of cigar leaf at that time constituted but slightly over 4 per cent of the total production, while in 1909 the production of cigar tobacco was 158,772,000 pounds, and the total for the United States 949,357,000 pounds. The production of cigar tobacco in 1909 was therefore close to 15½ per cent of the total for the period, which is an increase of more than 750 per cent in actual production and an increase in relative standing of more than 300 per cent. The total combined production of all tobacco has but little more than doubled during the period. The production of these cigar types in 1909 was distributed as shown in Table IV. The official crop-report figures of the Bureau of Statistics are used.

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[1] On the basis of 12 pounds to 1,000 cigars.

TABLE IV.—*Production, yield per acre, and value in 1909 of the cigar types of tobacco in the United States, by districts.*

Section.	Production.	Yield per acre.	Farm value per pound Dec. 1, 1909.
	Pounds.	*Pounds.*	*Cents.*
New England	29,655,000	1,638	15.9
New York	7,050,000	1,175	8.0
Pennsylvania	30,732,000	985	9.0
Ohio, Miami Valley	49,500,000	900	9.5
Wisconsin	37,170,000	1,180	9.2
Florida and Georgia	4,665,000	707	34.0
Total	158,772,000	....	....

By comparing Table IV with Table III (p. 18), showing the production in 1849 and 1859, it will be seen that this development took place entirely in connection with the areas as then established, except in the case of Wisconsin, which did not become of recognized importance until in the seventies.

The development of tobacco growing in Wisconsin from 1870 to 1880 was exceedingly rapid. In 1859 Wisconsin produced but 87,340 pounds of tobacco; in 1869, 960,813 pounds; and in 1879, 10,608,423 pounds. The maximum crop of tobacco was produced in Wisconsin in 1903, the figures for that year being 69,946,200 pounds, so that the 1909 crop is considerably below the best.

The Florida and Georgia area is a wrapper-producing section. The production is confined principally to Gadsden County and to contiguous areas across the State line in Decatur County, Ga. The tobacco is produced largely under expensive slat or cloth shade and comes more directly into competition with the imported Sumatra product than any other. It is the highest-priced type of tobacco produced in this country.

The New England area, confined principally to the Connecticut and Housatonic River valleys, is classed as a wrapper and binder section. The tobacco is produced mainly in the open, without shade, under intensive methods of fertilizing, cultivation, and handling. The highest-grade leaf makes acceptable wrappers for cigars and the remainder is principally useful for binder purposes. Since 1901 a considerable acreage of shade-grown tobacco has been produced in Connecticut each year. More recently there has been a marked expansion in acreage of shade-grown tobacco in that section, but with what degree of permanence of course remains to be revealed.

Figure 1 shows a typical field of Connecticut tobacco of the Havana seed variety, which is grown almost entirely in the portion of the New England area on the west side of the Connecticut River. Figure 2 shows a group of curing barns in the "Broadleaf" section of the New England district, which is principally on the east side of the river from Hartford to Springfield. Figure 3 shows an exterior view of a field of tobacco under cloth shade near Granby, Conn.

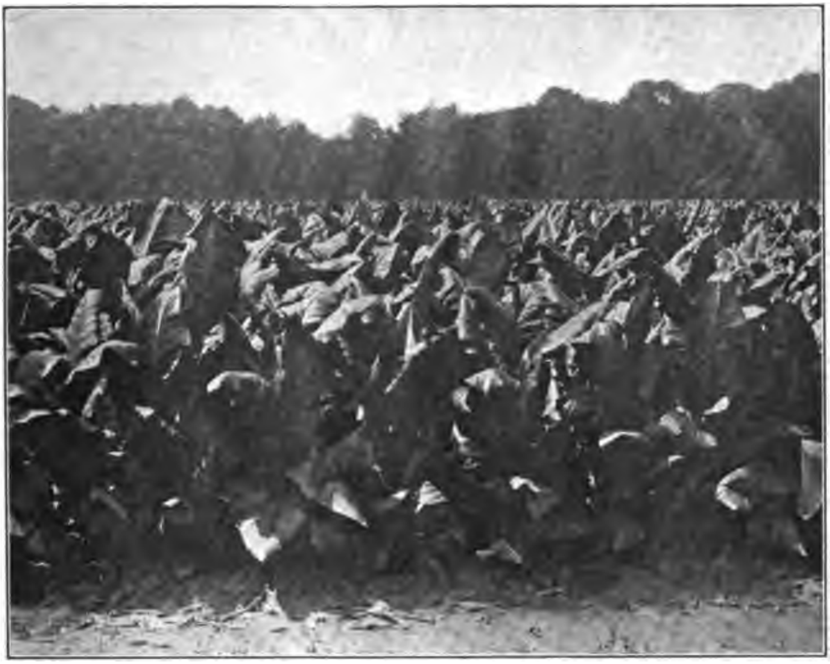

FIG. 1.—A Connecticut Valley tobacco field; variety, Havana seed. (Photographed by the Bureau of Soils.)

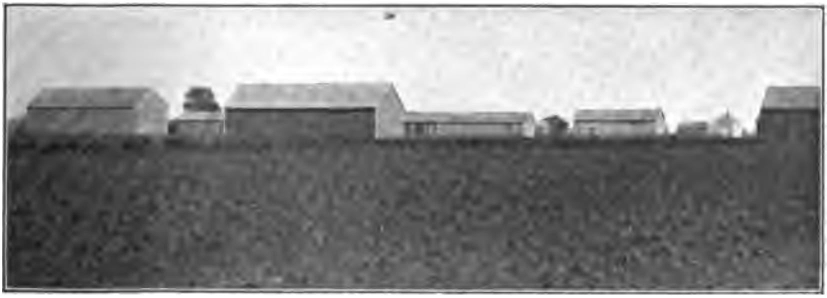

FIG. 2.—Group of curing barns in the broadleaf section of the Connecticut Valley. (Photographed by the Bureau of Soils.)

Some wrappers are produced also in the other cigar-tobacco producing areas, particularly in the Chemung Valley, New York, tobacco district; the northern part of Lancaster County, Pa.; and in Wayne and Medina Counties, Ohio; but the New England and Florida districts are the only recognized typical wrapper-producing sections. The other districts are typical producers of other types of leaf, as briefly described below. Figure 4 shows sweated shade-grown wrappers of the Sumatra type as produced in Connecticut and Florida.

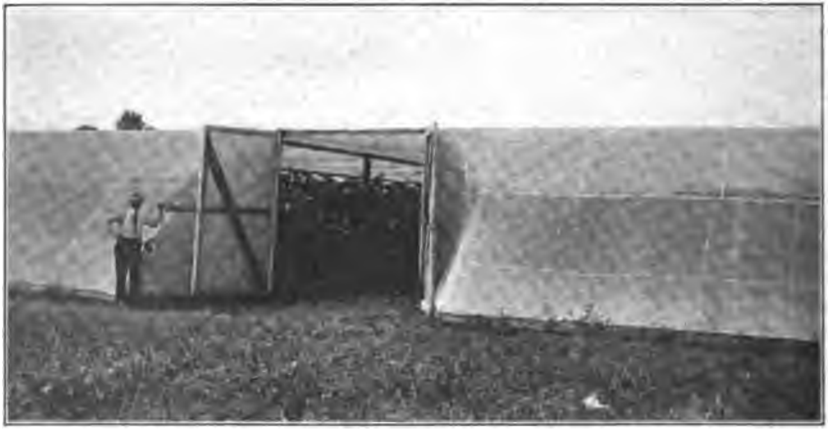

FIG. 3.—Exterior view of cloth shade, Connecticut Valley shade-grown tobacco, near Granby, Conn. (Photographed by the Bureau of Soils.)

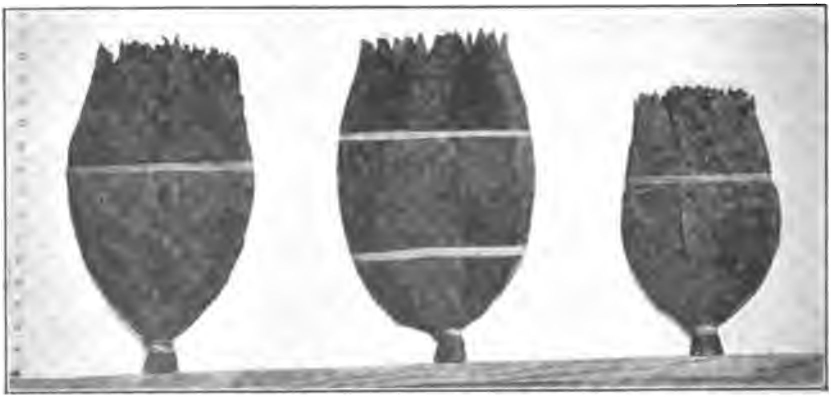

FIG. 4.—Hands of Sumatra-type shade-grown cigar wrappers, Florida and Connecticut. (Photographed by the Bureau of Soils.)

Wisconsin is particularly noted for the fine type of binder leaf which is produced. It is recognized by the trade as typically a binder State. Figure 5 shows a harvesting scene in the Wisconsin cigar-leaf district. The method shown is similar in the other northern cigar-tobacco districts. Figure 6 shows sweated Wisconsin binders 22, 18, and 14 inches long.

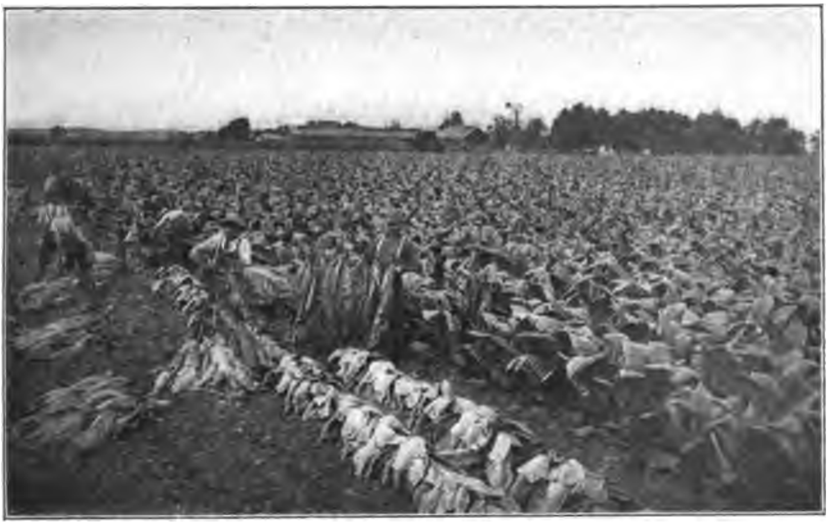

FIG. 5.—Harvesting cigar-leaf tobacco near Ganesville, Wis. (Photographed by the Bureau of Soils.)

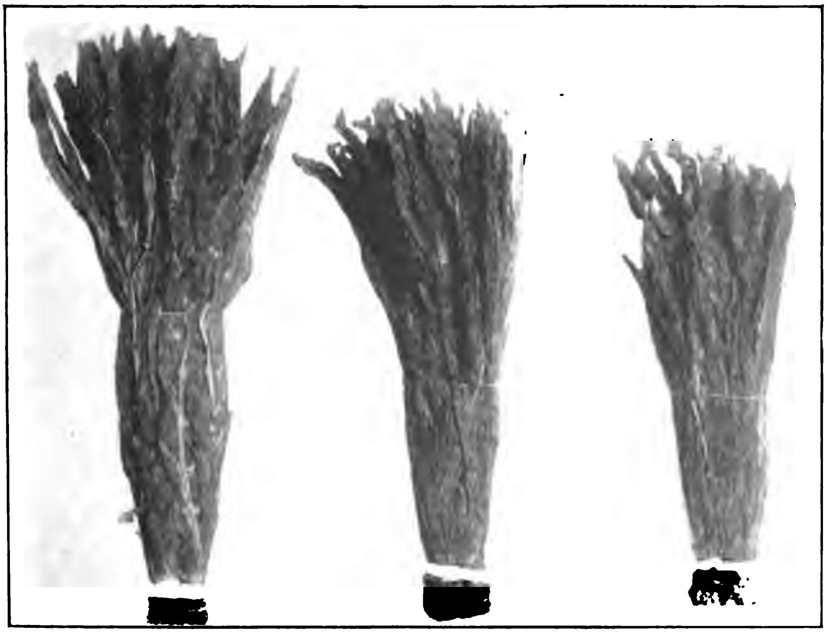

FIG. 6.—Sweated cigar leaf, Wisconsin binders, 22, 18, and 14 inches long, Wisconsin district. (Photographed by the Bureau of Soils.)

Ohio, in the Miami Valley district, is a leading producer of filler leaf, principally of the Zimmer Spanish type. Figure 7 shows samples of sweated Ohio fillers of the Zimmer type graded to differences of 1 inch in length.

The Pennsylvania and New York areas are classed as filler districts, except the Chemung or Big Flats area in New York, which produces more particularly a binder and wrapper type of leaf.

This whole scheme of division into types is only approximate, as all of the districts produce more or less of all three grades; that is, binder, wrapper, and filler. Furthermore, the distinctions between these grades are by no means fixed, particularly between the wrapper and binder grades.

An attempt has been made in recent years to establish the production of cigar filler and wrapper tobacco in certain other sections, principally in Texas and Alabama, but the production is not yet of commercial importance.

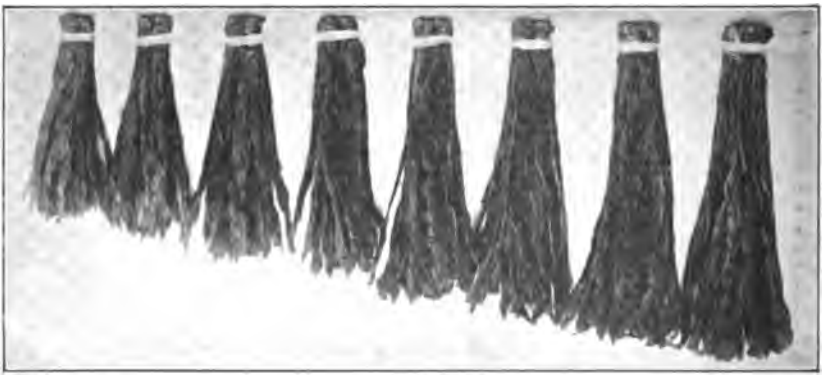

FIG. 7.—Sweated cigar leaf, Ohio cigar tobacco, Zimmer Spanish fillers, 11 to 18 inches long. (Photographed by the Bureau of Soils.)

Figure 8 illustrates the type of seed bed covered either with cloth or glass, as the conditions demand, common in the cigar-tobacco districts of the country.

DEVELOPMENT OF THE CIGAR-MANUFACTURING INDUSTRY.

The domestic manufacture of cigars has had an enormous development since the Civil War period. The number manufactured in 1863 was 199,288,284. In 1870 this number was increased to 1,139,470,774, and the increase has gone on at a rapid rate ever since and is now about 7,000,000,000 per year, the official figures for the fiscal year ending June 30, 1908, being 6,847,417,141. In addition, 1,152,525,926 little cigars (including all-tobacco cigarettes), weighing less than 3 pounds per thousand, were also manufactured in the same year.

In this development of the cigar-manufacturing industry, which began largely as a home industry with the grower working up leaf of his own production, the development has been more and more toward making this phase of the tobacco business also a factory-made and, to a certain extent, a machine-made product. This tendency has been very decided in the past 20 years, since the development of the bunch-making machines and suction tables. It still remains, however, the one striking phase of the tobacco-manufacturing business where the man of skill but without much capital and with no expense for machinery, working perhaps alone or with two or three assistants, has much chance for success.

The relative degree of concentration of these two branches of the industry can well be shown by stating that the official figures give the number of cigar factories operated in 1907 as 23,882, against 3,526 factories for the manufacture of all other forms of tobacco combined. Of these latter factories, 2,307 were devoted exclusively to the manufacture of smoking tobacco, although the smoking tobacco amounted to less than 50 per cent of the manufactured product, and in 580 factories cigarettes only were manufactured, leaving but 639 factories engaged in the production of all other forms of manufactured tobacco, including plug, twist, fine cut, and snuff.

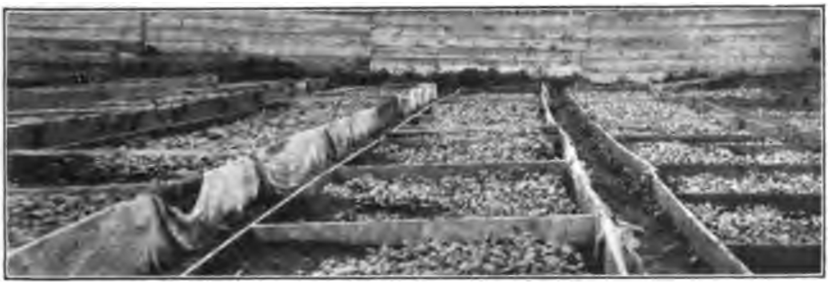

FIG. 8.—Type of seed beds common in all of the cigar-tobacco districts; covered either with glass, as in some of the northern districts, or with cloth.

DISTRIBUTION OF THE CIGAR-MANUFACTURING INDUSTRY.

Pennsylvania leads in the production of cigars, producing about 2,000,000,000 large cigars annually (average for 1907–1909, 1,840,000,000) with three very large centers of production—the Lancaster, the Philadelphia, and the Pittsburgh districts. Pittsburgh is noted particularly for its production of the class of low-grade cigars known as stogies.

New York ranks next in importance and produces annually about 1,300,000,000 large cigars (average for 1907–1909, 1,255,000,000) so that these two States together produce almost 50 per cent of the total output of the country. Greater New York is the largest single producing center for the manufacture of cigars, producing nearly 1,000,000,000 large cigars yearly.

Richmond, Va., is particularly noted for the production of the class of low-grade cigars known as cheroots, and this district is credited with a production of about 250.000,000 large cigars yearly.

The all-Havana cigars manufactured in this country are largely produced in Tampa and Key West, Fla., where climatic conditions for the proper mellowing, aging, and handling of the imported leaf are believed to be more nearly like those existing in Havana, Cuba, than elsewhere in this country.

The production of small cigars (weighing less than 3 pounds per thousand) is centered at Baltimore, Md., and at Danville and Richmond, Va. Together these three districts manufacture about 75 per cent of all the little cigars and all-tobacco cigarettes produced in the country. Nearly all of the remaining production is concentrated in New York City and Philadelphia.

DEVELOPMENT OF THE EXPORT AND MANUFACTURING TYPES OF TOBACCO.

In the early days the cultivation of tobacco in Virginia was largely confined to the tidewater section, particularly the rich river lands of the James, the York, the Rappahannock, and the Potomac Rivers. As settlements were pushed farther inland, however, tobacco culture was carried along simultaneously.

In the earliest attempts at growing tobacco in Virginia it is fair to suppose that not much differentiation of type was recognized but the development of the industry had not progressed far until at least two general types were recognized, one the so-called sweet scented and the other known as Orinoco. This distinction is now lost so far as differentiating Orinoco from any other general type of superior sweetness is concerned.

With greater refinements in taste, which of course were reflected in improvements in manufaçturing processes, better defined ideas of quality in tobacco were developed. In the Virginia area particularly it was observed that the tobacco produced on the clay hill lands was of better body, finer texture, and of superior richness and luster, and it came to be much preferred to the coarser and rough tobaccos of the river bottom land.

The ordinary sandy coastal-plain soil produced a mild, sweet tobacco, but the yield was much too small.

The main differentiation of type of tobacco in the early days was probably as it is to-day, namely, between the dark, heavy, strong types and the lighter and milder types; and this of course was succeeded by a great number of subsidiary refinements of quality within the two broad classes.

Even before the outbreak of the Civil War the cultivation of tobacco in Virginia was almost completely abandoned in the tide-water section and was confined mainly to the middle and piedmont section of the State between the Blue Ridge and the coastal plain. The great bulk, fully 90 per cent, of Virginia tobacco is now produced south of the James River, but more or less tobacco is grown, mostly of the "Sun-Cured" type, as far north as Fredericksburg and Charlottesville.

DEVELOPMENT OF DIFFERENT METHODS OF CURING TOBACCO.

From the earliest colonial history we learn that the Indians were in the habit of curing leaves of tobacco in the sun or by hanging them in the hut or wigwam where the heat and smoke of the open fire assisted in the cure. The colonists themselves, however, soon began the erection of special log houses for curing the tobacco, which were left more or less open between the logs so that the air could pass through without exposing the tobacco too much to the weather. Figure 9 shows one of these older types of log barns. Unfortunately they are still to be seen here and there in some sections.

The origin of the use of fire in the curing process found its principal reason in the early days in the necessity for protecting the tobacco against damage by pole sweating or house burning as it is more generally called. It was also soon learned that the tobacco cured by open fires kept much better, especially if it was to stand a long ocean trip. It was true also that the desirable qualities of the light, mild tobaccos would be obscured and negatived by heavy firing with smoky fires, which would not be the case with the heavy types, whose rankness would be modified and quality improved by the heat used and the creosotic flavor imparted.

In the early days the British colonial policy demanded that the product of her colonies be shipped only to England. The product of Virginia, therefore, consisting mostly of open-fire and smoke-cured tobacco, went directly to England and was there used for home consumption and distributed by her merchants to continental countries. The habit of using this heavy fire-cured tobacco of smoky flavor, therefore, became firmly fixed in a number of the nations of Europe which used American tobacco. Habit is everything in the use of tobacco and the tobacco user desires what he has been in the habit of having. The reasons for continuing the practice of fire curing the dark, heavy-bodied tobaccos which we produce for export purposes are, therefore, nearly as strong to-day as ever.

Owing to the light nature of its soil, southern Maryland has always produced a light-colored and light-bodied tobacco possessing little gum or oil, which keeps well if properly conditioned when only air-cured. Fire is not necessary in the curing except in damp, muggy weather. Fire curing has never been the factor in curing Maryland tobacco that it was and is with the heavier bodied Virginia tobaccos, so that to-day fire curing in southern Maryland is almost never practiced and Maryland tobacco is essentially an air-cured product. It is interesting to note in this connection that Maryland, having been granted a palatinate form of government, was not subject to the British colonial laws and could, therefore, find a market where she pleased. Much of her tobacco, therefore, went directly to the European markets, particularly France and Holland, and so strong is habit in influencing the use of tobacco that these two nations have continued to take annually the bulk of the tobacco Maryland produces.

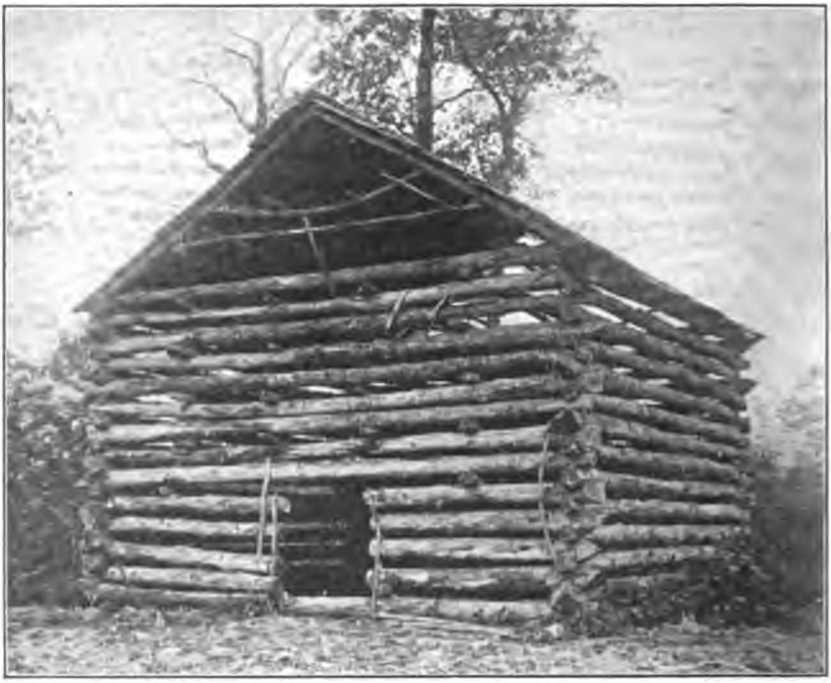

FIG. 9.—Early type of log curing barn for air-curing tobacco still seen in some of the Virginia, Kentucky, and Tennessee districts.

Much of the soil in the southern tier of counties in Virginia, particularly in Mecklenburg, Halifax, Pittsylvania, and Henry Counties and immediately across the North Carolina line in Granville, Person, and Caswell Counties, is of a thin, light, sandy character upon a yellow, sandy, clay subsoil. The tobacco produced on these soils was mild and fine, of good body, tending to cure naturally to a mottled orange or yellowish-red to brown color.

This type of tobacco was found to be particularly pleasing to the domestic taste for chewing and smoking purposes and, as the home trade has never cared for the smoky flavor on tobacco, it became the custom to cure this type largely by air, open fires being resorted to only when necessary. In order to keep down the flavor of smoke, growers after a time learned to use charcoal instead of wood when heat was necessary in curing this type. By proper management of these fires in close barns, with arrangements for ventilation in the proper manner and at the proper time, it was discovered that the fires could be used to great advantage in making the colors still brighter and of greater uniformity, developing at the same time an agreeable and characteristic sweet scent and flavor.

In this coal system of curing, the barns were tightly daubed between the logs and small fires were built in depressions in the earth floor of the barn about 4 feet apart each way. The labor involved in making the charcoal was very great and the task of walking around in the hot barn at frequent intervals day and night for several days to attend the fires was a very disagreeable one.

The most important step forward in developing the method of curing this type of tobacco was in the use of flues, at first built of rock or brick and finally of sheet iron. With this arrangement the mouth of the furnace was on the outside, any kind of wood that would burn satisfactorily could be used, the heat would pass through the flues, thus maintaining a much more uniform and satisfactory temperature, and the smoke finally pass out of the smoke pipes without imparting a smoky flavor to the leaf or discoloring it in any way. The use of sheet-iron flues with brick or stone furnace openings has now become the universal practice throughout all the bright flue-cured belt.

The methods of managing the cure with these flues have been reduced to a high art and the flue-cured type of tobacco has become one of the most useful and satisfactory tobaccos for both domestic use and export.

Thus we have, as finally developed, three distinct methods of curing tobacco: (1) The method of curing by air, that is, simply hanging the tobacco up in barns, with natural ventilation subject to more or less artificial control; (2) the open-fire and smoke method; and (3) the flue-cure method.

Since the war period little, if any, new territory has been added to the open-fire cured types and the production has a tendency to decrease rather than to increase. On the other hand, the air and flue-cured types have enormously increased in acreage and production.

At the present time the average annual production of the air-cured types of tobacco is about as follows:

	Pounds.
Cigar tobacco	160,000,000
Burley	215,000,000
Green River	35,000,000
One-Sucker type	30,000,000
Virginia sun and air cured	10,000,000
Maryland	20,000,000
Total	470,000,000

These air-cured types thus constitute more than 50 per cent of the total production of the country and, with the exception of the Maryland type, are used principally in domestic manufacture for domestic consumption. The most important of these air-cured types, particularly the cigar tobaccos and Burley, have received their greatest development since the Civil War.

The annual production of the dark types of tobacco cured by open fires is substantially as follows for the types of much importance:

	Pounds.
Virginia dark	52,000,000
Hopkinsville and Clarksville	70,000,000
Paducah	60,000,000
Henderson or Stemming	35,000,000
Eastern Ohio export	3,000,000
Total	220,000,000

The eastern Ohio export type, while it is an open-fired tobacco, can not properly be classed as a dark, heavy-bodied type, and it is really a type quite distinct from the other fire-cured types which are all dark, rich, heavy sorts. Eastern Ohio export tobacco more closely resembles the Maryland type, moves to market through the same trade channels, and is described more at length in connection with this type of tobacco.

All of these fire-cured types had reached approximately their present state of development and annual production prior to the Civil War period.

The annual production of the flue-cured type of tobacco averages about as follows:

	Pounds.
Old Belt (Virginia and North Carolina)	125,000,000
New Belt (eastern North Carolina and South Carolina)	95,000,000
Total	220,000,000

While this type had its beginnings several years before the Civil War period, it is nevertheless in its present development essentially a new type and indeed its great development on its present basis has taken place mostly since 1890, especially in the New Belt section.

THE DARK-FIRED TYPE OF TOBACCO.

The dark-fired type of tobacco was produced extensively for export purposes in Virginia in the early days. It has continued to the present time to be the type chiefly grown for this purpose and, indeed, by far the larger portion of this type now produced is exported and, conversely speaking, it forms the major portion of our tobacco exports. The soils upon which these dark-fired types of tobacco are produced vary considerably in character, but they are all of a class generally spoken of as strong, durable soils rather than light and leachy, running more to clay than to sand. In every case they are underlain by the strong, rich, clay subsoils, generally red in color, which are so common over the uplands of middle Virginia and western Kentucky. In harvesting, the entire plant is cut after splitting the stalk downward to within a few inches of the point of cutting off. The stalk is then inverted and straddled over the stick to hang for curing, rather than being speared on as is the practice with some other types, notably the cigar types and the Maryland type

DOMESTIC DEMANDS.

No extensive domestic taste has been developed for this strong, smoky-flavored type of tobacco. As a whole, the production or demand for this type has not developed much in recent years, and the maximum production was reached approximately in the fifties and seventies of the last century. In several of the European countries and in Great Britain, however, the taste for this class of tobacco is well established and the yearly demand in this country for export purposes is substantial and fairly steady.

A considerable quantity of the aggregate annually finds its way into domestic consumption, principally in the form of snuff. Some wrappers for domestic plug are also obtained from this type and a small amount of low-grade so-called Greenville plug, manufactured for domestic use, is made partly or entirely from this type. Originally this type of plug was manufactured almost exclusively in Greenville, Muhlenberg Co., Ky., from which town it took its name. The tobacco of that section was less heavily fired than in some others, and three or four factories (large for the old days) were devoted to this industry. These factories are now mostly dismantled, and what little Greenville is still put up is mostly manufactured elsewhere.

Definite figures are not available, but for all purposes it is probable that some 30,000,000 to 35,000,000 pounds of this dark-fired type of tobacco finds its way into domestic consumption yearly.

Snuff is by far the most important item in this domestic consumption, and extensive leaf-handling plants are centralized for the

Kentucky-Tennessee district at Clarksville, Tenn., and in the Virginia dark district at Lynchburg, Va. The predominating requirements for snuff are met by the strong, fat, rich grades, but, since other requirements are not exacting, the class of leaf used is classed only as common to medium.

The leaf of this type of tobacco used as wrappers for plug, both for domestic use and export, is the highest grade produced. The requirements for size, body, fineness, color, etc., are so exacting that the proportion to be found in any crop is small. The wrappers are picked up here and there, usually in small lots averaging less than 100 pounds. Because of favorable soil conditions these wrappers are obtained mostly in the region subsidiary to Lynchburg in the Virginia dark district as a market center and in the Clarksville district in Tennessee. These dark wrappers are bought at farm prices ranging from $12 to $25 for 100 pounds, but the quantity is so small that it raises but slightly the general average price for the type as a whole, which in the past 10 years has averaged from about $5 to $9 per 100 pounds, although individual crops sometimes sell at double the general average or more. An uncertain and at most a very small proportion of this dark-fired type is also used in the manufacture of cheap domestic cigars, some of them of the Italian type for the large Italian population in and about New York City. Generally speaking, however, this dark-fired type of leaf is too strong and rank to be used in the manufacture of cigars for domestic use. Its use in this way is really an anomaly in the shape of an exception to prove the rule of its unfitness for the purpose.

FOREIGN DEMANDS.

This dark-fired tobacco is the principal export type. Of the total annual production, which aggregates about 220,000,000 pounds, some 185,000,000 or 190,000,000 pounds are exported. This type thus constitutes more than 50 per cent of our total leaf exports, amounting to more than 300,000,000 pounds annually.

Great Britain, Italy, Germany, France, Spain, Austria, and Belgium, in about the order named from the standpoint of quantity taken, are the principal foreign purchasers and consumers of this type of leaf. Among these countries, Italy, France, Spain, and Austria are known to the tobacco trade as régie purchasers: that is, the tobacco industry in these countries is a Government monopoly and the tobacco is, therefore, purchased by agents for the account of the Government. Italy, France, and Austria conduct the monopoly directly under Government auspices, but in the case of Spain the monopoly privilege is let out under certain restrictions for a period of years to a private concern known as the Compania Arrendataria de Tobaccos. The purchases of Austria and Italy in this country are practically all of this dark-fired type, and the total purchases of this type by these countries is thus accurately known.

Next to the plug wrappers mentioned above, Austria and Italy take the highest grade leaf of this type. Their requirements are for a leaf of good size, smooth, with plenty of life and elasticity, fine, and with solid, uniform color. This tobacco is used in the manufacture of cigars. The finest leaves are used for wrappers and other grades for filler purposes. Austria demands a lighter brown color than Italy, and generally pays a somewhat higher price. The larger percentage of the Austrian leaf is obtained in the Virginia dark districts while most of the Italian leaf is obtained from the Clarksville, Hopkinsville, and Paducah districts of Kentucky and Tennessee.

Austria-Hungary takes on the average, according to their own trade reports (nearly all goes to the Austrian Régie), about 6,000,000 or 7,000,000 pounds of leaf tobacco annually from the United States, all of the better grades of this dark-fired type.

Italy generally takes from 30,000,000 to 40,000,000 pounds annually, practically all of which is also of the good to best grades of the dark-fired type.

Germany and the German ports, principally Bremen, are also important outlets for large quantities of the medium to good grades of dark-fired leaf, constituting the larger portion of the 30,000,000 to 40,000,000 pounds of imports of leaf tobacco from the United States. The German grades are obtained particularly from the Clarksville district in Kentucky and Tennessee, and also in the Lynchburg section of the Virginia dark district.

The United Kingdom is the heaviest single purchaser of the dark-fired type of tobacco. The total purchases of all types amount annually to 100,000,000 pounds or more, of which about 50 per cent is of the dark-fired type. The great source of supply of British dark leaf, however, is in the Henderson or Stemming district of western Kentucky, although buyers for the English trade are active purchasers also in all the other dark-fired districts in Kentucky, Tennessee, and Virginia. Great Britain takes a number of grades of dark tobacco, including the low, medium, and high grades.

The British import duty is very high, 88 cents a pound in 1910, and in order to offset this as much as possible, it has been the custom to stem the tobacco in this country before shipment, so as to reduce the weight of the tobacco paying the high duty. The Stemming district received its name because so large a percentage of tobacco produced there was stemmed preparatory to shipment to Great Britain. A differential duty on strips has in recent years materially reduced the percentage of tobacco that is stemmed before shipment to Great Britain.

France generally purchases about 30,000,000 pounds of tobacco in this country yearly, subject to quite wide fluctuations in particular years, much of which is of the dark-fired types and consists principally of the lighter-bodied tobacco of medium to low grade. Much the larger percentage of the dark-fired tobacco taken by France is from the Paducah district of Kentucky and Tennessee.

The Spanish buyers take low-grade tobacco wherever it can be obtained cheapest. Their purchases in this country fluctuate considerably, according to the price of tobacco. The quantity of American tobacco purchased by Spain generally ranges from 10,000,000 to 20,000,000 pounds annually, most of which is usually of the lowest nondescript grades of dark-fired leaf.

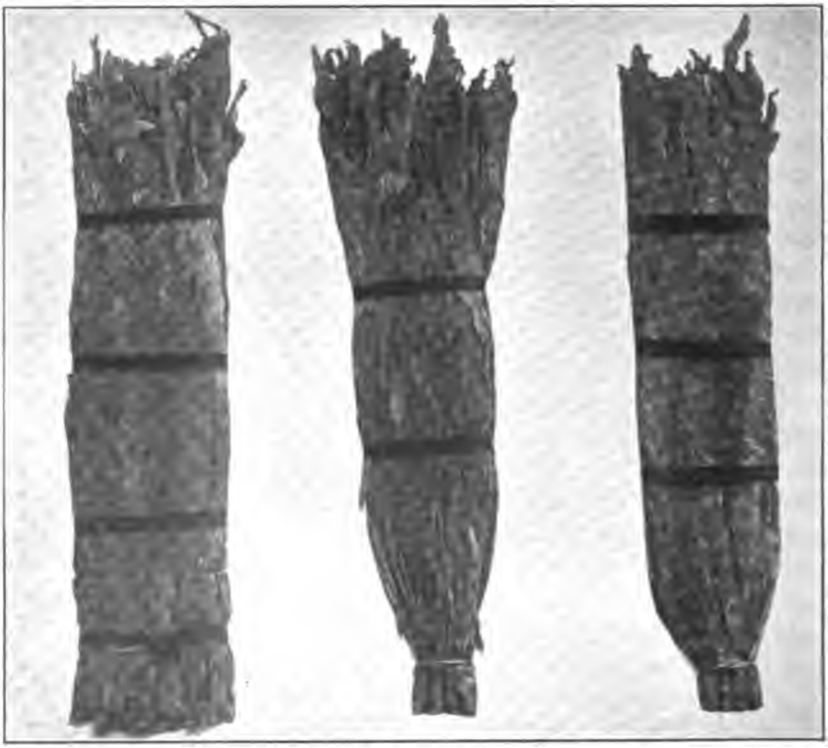

FIG. 10.—English strips, English leaf, and Austrian leaf tobacco from the Virginia dark-fired district. (Photographed by the Bureau of Soils.)

The Belgium trade is also estimated to take 2,000,000 or 3,000,000 pounds annually of this dark-fired type of leaf of a grade and quality about like that taken by France.

Several million pounds of rather coarse but very long, dark tobacco is tied in the customary small bundles and prepared by special treatment for export to Africa to be sold in the leaf at retail to the natives.

Leaf of a like nature, often spoken of as black fat or black horse, is similarly prepared for export to parts of the West Indies, Mexico, and a number of Spanish-American countries of Central and South America. A portion of this type of leaf aggregating probably some 5,000,000 pounds or more is obtained from different parts of the dark-fired districts of the country where leaf of suitable length and reasonable price may be obtained, although the presence of smoke on the leaf is not an essential requisite. Much of this "rehandling" type, as it is generally called, is obtained also from the One-Sucker districts of Kentucky and Tennessee and southern Indiana.

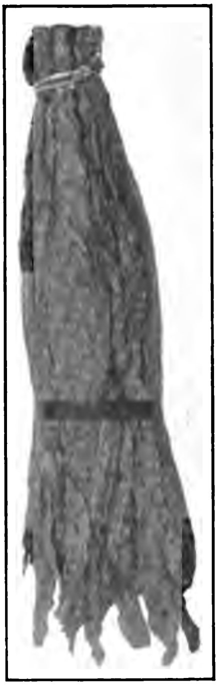

FIG. 11. - Dark-brown "snuffer" tobacco from the dark-fired districts of Kentucky, Tennessee, and Virginia. (Photographed by the Bureau of Soils.)

Figures 10 and 11 show samples of some of these various standard types, produced in the dark-fired districts of the country.

REVIEW OF THE DARK-FIRED TYPE BY DISTRICTS.

THE VIRGINIA DARK DISTRICT.

The annual production of dark-fired tobacco in Virginia is about 52,000,000 pounds, or about 25 per cent of the total production of this type. The Virginia State Department of Agriculture now collects accurate figures of the first-hand sales of tobacco in Virginia by markets, but nothing is available of an accurate statistical nature to show the distribution of the acreage of the different types of tobacco produced in the State. Dark-fired tobacco, however, constitutes not quite one-half of the total annual production of the State, distributed by counties, according to the best estimates obtainable, about as shown in Table V.

TABLE V.—*Estimated annual production of dark-fired tobacco in Virginia, distributed by counties arranged from west to east.*

Counties.	Pounds.	Counties.	Pounds.
Albemarle	500,000	Amelia	1,700,000
Nelson	2,500,000	Charlotte	4,000,000
Botetourt	500,000	Prince Edward	4,000,000
Rockbridge	250,000	Cumberland	2,100,000
Franklin	500,000	Powhatan	800,000
Bedford	6,000,000	Chesterfield	600,000
Amherst	3,500,000	Lunenburg	2,500,000
Fluvanna	250,000	Mecklenburg	2,000,000
Buckingham	5,200,000	Brunswick	1,500,000
Appomattox	3,000,000	Dinwiddie	3,500,000
Campbell	5,000,000		
Pittsylvania	250,000		
Nottoway	3,000,000	Total production of dark-fired tobacco in Virginia	52,000,000

Of the 23 counties in Virginia that produce commercial quantities of dark-fired tobacco, only about 15 produce each as much as 1,000,000 pounds a year.

The regular Virginia dark-fired type of tobacco, frequently designated "brown shipping" to differentiate it from the olive-green or black stemming subtype, is marketed loose at auction at the various sales warehouses scattered throughout the dark-tobacco section.

Lynchburg is the largest of these markets and alone handles about one-third of the entire dark-fired crop of the State. Other important dark markets are Farmville, Petersburg, Drakes Branch, Blackstone, Bedford City, and Brookneal. A number of smaller markets are located at other points.

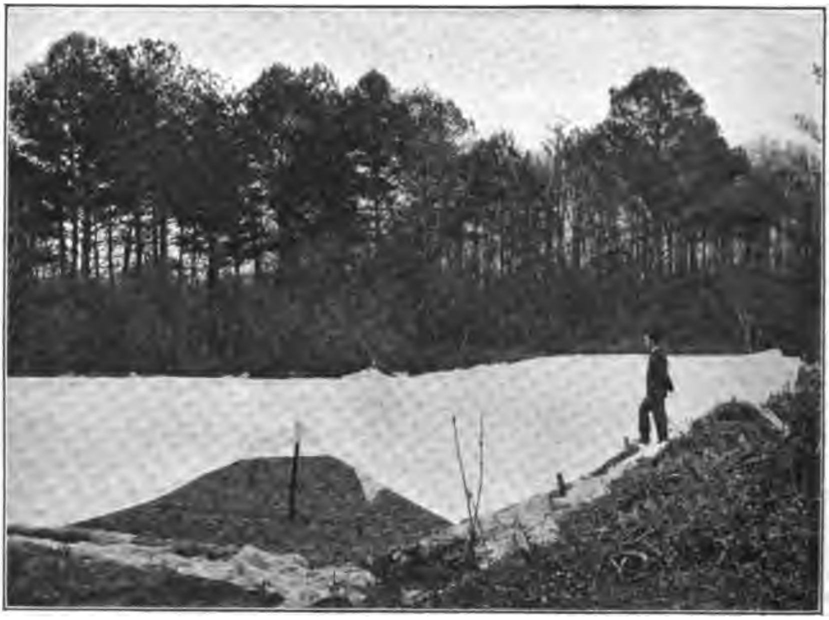

FIG. 12.—Plant bed in woods, with cloth covering, showing the common method of growing plants in nearly all the export and manufacturing tobacco districts. (Photographed by the Bureau of Soils.)

The proportion of fine grades is generally considered to be larger in the Virginia dark-fired crop than in the western crop as produced in Kentucky and Tennessee, and the colors as a whole do not run quite so dark as does the "western" tobacco. As a whole, the heaviest bodied and best-textured dark-fired tobacco of Virginia is produced on the strong soils of the western portion of the district lying tributary to Lynchburg as a market center. A larger percentage of leaf suitable for plug wrappers is obtained from this section than from any part of the dark-fired district. The rich but fine-textured chocolate soils in the coves among the hills scattered here and there along Stonewall and Bent Creeks, in the northern part of Appomattox County, and along Goose Creek, in Bedford County, are especially famous locally for the high percentage of leaf which they produce suitable for plug wrappers and other high-grade purposes. Charlotte County, as a whole, is noted for the large proportion of tobacco it produces which is particularly adapted to the requirements of the Austrian Régie, for plug wrappers, and other high-grade purposes. The Cub Creek section of this county is particularly famed because of the excellent quality of the leaf produced.

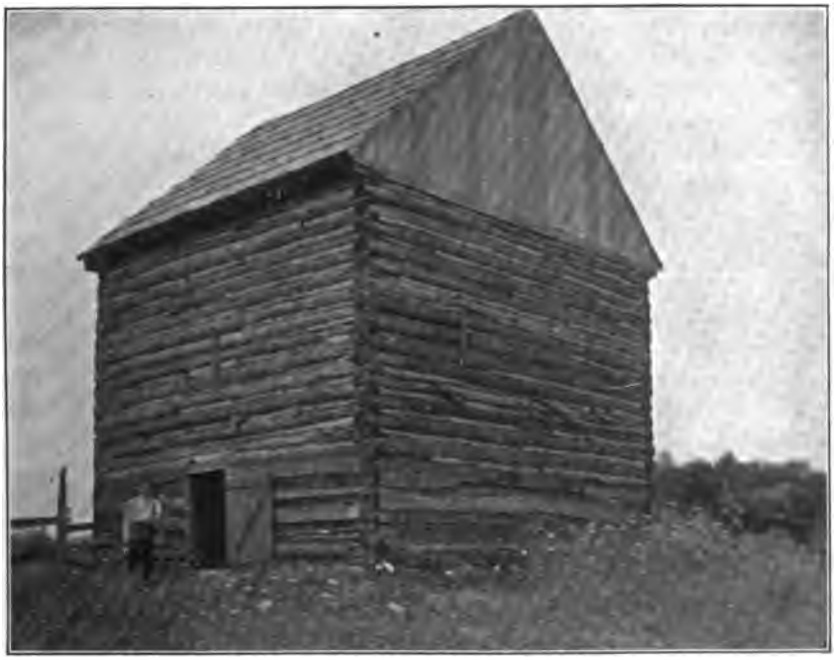

FIG. 13.—Common type of Virginia log barn for curing dark tobacco with open fires. (Photographed by the Bureau of Soils.)

Figure 12 illustrates the type of seed bed common not only in the dark-fired Virginia district but in nearly all of the other export and manufacturing tobacco districts as well. A clearing is made on suitable land in the woods which is to be worked up after burning brush on the land to destroy weeds and insects and mellow the soil. The cheesecloth cover protects the young plants from cold and keeps off flying insects, which are frequently very troublesome to unprotected beds.

Figure 13 shows a characteristic log barn, tightly chinked and daubed with mud, common in Virginia and elsewhere, for curing dark tobacco by open fires on the earthen floor.

A considerable proportion of the rich, fat leaf suitable for the Bremen trade and for export to England is also found in the Lynchburg district. Dark Virginia leaf or strips from this section are generally spoken of by English dealers as Lynchburgs.

Good, rich leaf suitable for snuff stock is also obtained from the Lynchburg district in considerable quantities.

About 5,000,000 pounds of plug for export is manufactured yearly, principally from Virginia dark-fired leaf. Most of this plug is manufactured at Petersburg, Va., and much of it is marketed in Australasia.

DISTRIBUTION IN USE OF THE VIRGINIA DARK-FIRED TYPE.

Accurate figures of a statistical nature are not to be obtained as to the exact final disposition of the dark-fired tobacco of Virginia or, indeed, of any other type.

Table VI shows estimates based on general information of a private nature obtained from members of the tobacco trade.

Table VI.—*Estimated distribution in use of Virginia dark-fired tobacco.*

Kind and place.	Pounds.	Kind and place.	Pounds.
Wrappers for plug	1,000,000	Spain	1,500,000
Austria	5,000,000	Miscellaneous export trade, principally Belgium, Norway, and Sweden	6,000,000
Italy	4,000,000	Snuff and miscellaneous domestic consumption	8,000,000
France	3,000,000	Total	52,000,000
Germany and Bremen	8,000,000		
Great Britain	7,500,000		
Export plug and Australia	6,500,000		
African and rehandling	1,500,000		

OLIVE-GREEN OR BLACK STEMMING DISTRICT.

Along the northern border of this dark-fired section in Virginia, just south of the James and Rivanna Rivers, is a stretch of country in which production is rather scattered and in which a modified type of fired tobacco is produced, known as olive-green or black stemming tobacco. The aggregate production of this type of leaf is about 2,000,000 pounds yearly, divided among the counties about as shown in Table VII.

Table VII.—*Estimated annual production of olive-green or black stemming tobacco in Virginia, distributed by counties arranged from east to west.*

Counties.	Pounds.	Counties.	Pounds.
Chesterfield	100,000	Fluvanna	250,000
Amelia	200,000	Albemarle	350,000
Powhatan	800,000	Total	2,000,000
Cumberland	100,000		
Buckingham	200,000		

The region of country in which the olive-green or black stemming type of tobacco is grown has been separately outlined on the map (Pl. I), as it is really a type quite distinct, although it has been included in Table V of 23 counties, covering the entire production of open-fire cured tobacco in the State, and in Table VI, showing how the type is distributed in use.

Olive-green tobacco is produced mostly from seed of the One-Sucker type, and it is a long, rich, heavy-bodied but rather coarse tobacco. Although cured by open fires, the method of curing is considerably modified as compared with other open-fire cured types, and the tobacco is cured up at once without yellowing, if possible, to a uniform olive green. Tight barns, high heat from the outset, and sappy tobacco are the main features in obtaining a good cure. So high and sustained is the heat that the cure is completed usually in 36 to 48 hours. The difficulty is in getting the color uniform and solid, which when successful varies in shade from olive green to very dark brown and black.

England has been practically the sole purchaser of this type of tobacco, and until recently it was mostly stemmed before shipment. A strong odor of smoke is also desired and, because of this, much of this type after purchase from farmers is rehung on sticks and placed in special barns and heavily smoked by open fires with hardwood for a period of a week or more to give a strong creosotic flavor. A considerable portion of this type is bought and handled at Amelia, Va., where it is bought direct from the wagon at private sale.

DARK-FIRED TOBACCO IN KENTUCKY AND TENNESSEE.

Originally introduced from Virginia, the quantity of dark-fired tobacco grown in Kentucky and Tennessee now amounts to fully three times the Virginia production, and to distinguish it from "Virginia dark" it is generally spoken of as "western" tobacco.

Three subdivisions of this western dark-fired section are well recognized: (1) The Clarksville and Hopkinsville district, (2) the Paducah or Western district, and (3) the Henderson or Stemming district.

THE CLARKSVILLE AND HOPKINSVILLE DISTRICT.

In recent years the production of the Clarksville and Hopkinsville district has averaged about 70,000,000 pounds annually, about 40,000,000 pounds being produced on the Kentucky side and 30,000,000 on the Tennessee side. This district has the reputation of producing a somewhat better grade of leaf on the whole than either of the other western dark districts, which generally outsells the others by as much as a cent or more a pound for the average of the entire crop. The portion of this district tributary to the Clarksville, Tenn., market produces some of the finer grades, suitable for plug wrappers and the Austrian and Italian Régie and German and Bremen requirements particularly. The McAdoo and Red River section in the western portion of Montgomery County and in Robertson County is particularly noted for the fine grades of leaf produced. Figure 14 is

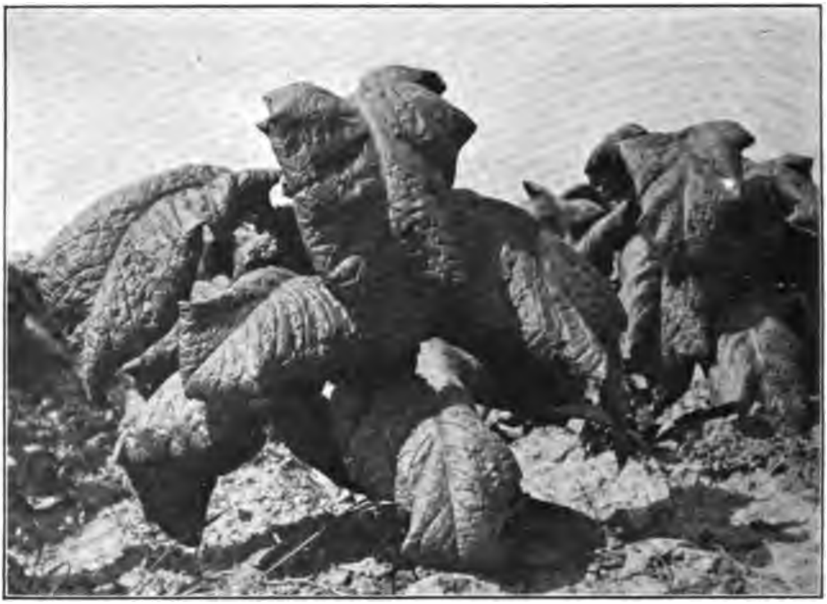

FIG. 14.—Characteristic tobacco plant of the Clarksville type, Montgomery County, Tenn. (Photographed by the Bureau of Soils.)

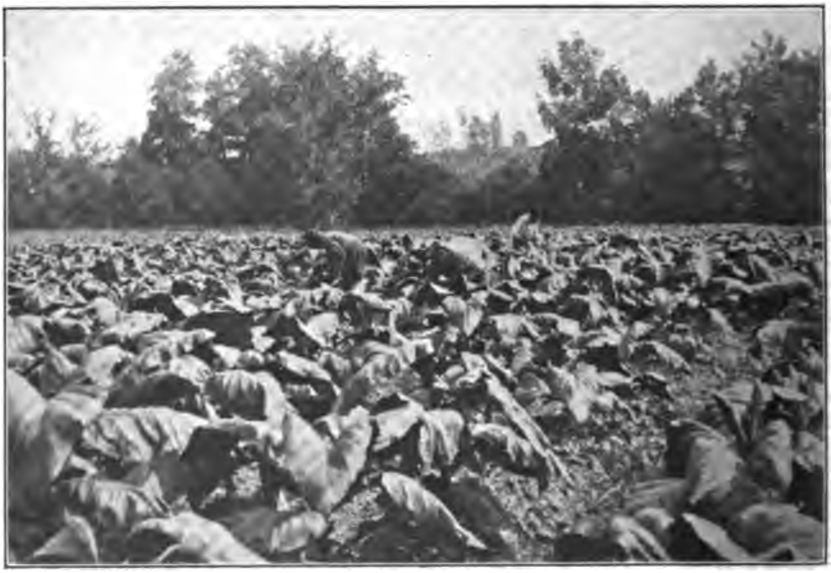

FIG. 15 —Worming and suckering tobacco in the Clarksville district, Montgomery County, Tenn. (Photographed by the Bureau of Soils.)

an illustration of the characteristic large, broad, and heavy leaf (Pryor) type of plant generally grown in the Clarksville district. Figure 15 shows a field of this type near Clarksville from which the worms and suckers are being removed, a tedious but very necessary operation; and figures 16 and 17 present characteristic scenes common over much of the export and manufacturing tobacco territory.

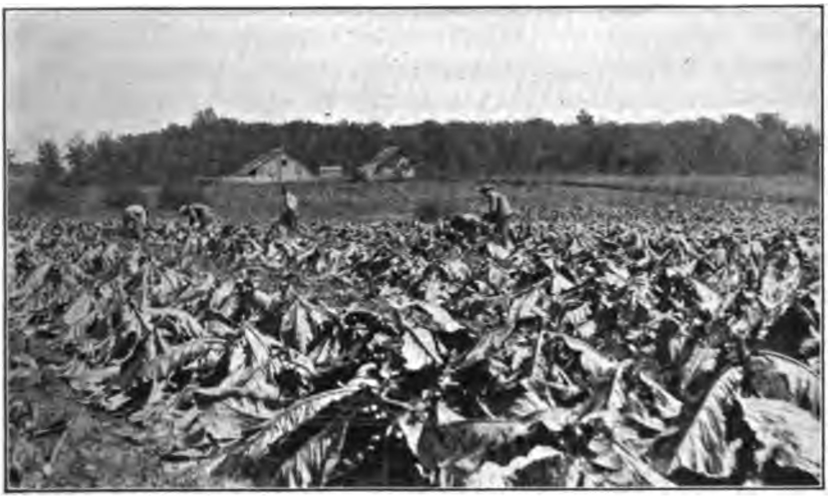

FIG. 16.—Harvesting scene, Clarksville district, Montgomery County, Tenn. (Photographed by the Bureau of Soils.)

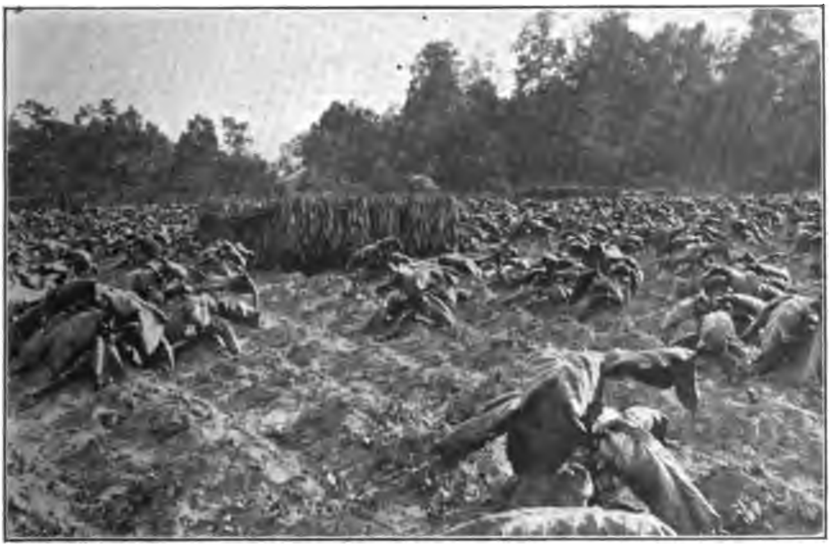

FIG. 17.—Wilting and yellowing tobacco on the scaffold, Clarksville district, Montgomery County, Tenn., showing a common method in nearly all districts. Plants that were unripe at the time of cutting remain standing in the field. (Photographed by the Bureau of Soils.)

Production is most concentrated in Montgomery and Robertson Counties, in Tennessee, and the southern portion of Christian, Todd, and Logan Counties, in Kentucky. The Clarksville district extends into six other counties in Tennessee, all bordering on Montgomery or Robertson Counties. The distribution of production of this type in Tennessee is estimated with approximate accuracy in Table VIII.

TABLE VIII.—*Estimated annual production of Clarksville type of tobacco in Tennessee, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.
Montgomery	10,000,000	Houston	750,000
Robertson	10,000,000	Sumner	500,000
Cheatham	3,500,000	Davidson	250,000
Stewart	3,000,000		
Dickson	2,000,000	Total	30,000,000

In Kentucky the Clarksville and Hopkinsville district extends in whole or in part into eight counties, an estimate of the annual production of which is shown in Table IX.

TABLE IX.—*Estimated annual production of the Clarksville and Hopkinsville type of tobacco in Kentucky, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.
Christian	13,000,000	Muhlenberg	2,000,000
Logan	7,000,000	Lyon	2,000,000
Trigg	6,000,000	Simpson	1,000,000
Todd	6,000,000		
Caldwell	3,000,000	Total	40,000,000

The tobacco produced in Muhlenberg, Caldwell, and Lyon Counties is of a mixed type, and can not be classed strictly in either the Hopkinsville, Henderson, or Paducah districts. It is buffer territory and the lines dividing the districts, as shown on the map, are somewhat arbitrary, but are the best approximations practicable. Muhlenberg County is buffer territory between four districts, the Hopkinsville, the Stemming, the Green River, and the One-Sucker or southern Kentucky districts. Most of the tobacco grown in Muhlenberg is produced in the southern and western portions of the county and most of it is at least lightly smoke-cured by open fires. That from the southern portion finds its way to market mainly through the Hopkinsville district and that from the western part mainly through the Stemming section. The northeastern part of Muhlenberg is largely given up to coal mining and but little tobacco is produced in that section. Muhlenberg tobacco is designated by some as the Greenville type, from the name of the county seat, which was formerly an important center for the manufacture of the so-called Greenville plug. The total production of tobacco in Muhlenberg County is about 3,000,000 pounds annually, of which 2,000,000 pounds have been classed with the Hopkinsville district and 1,000,000 pounds with the Henderson or Stemming district.

Likewise the product of Caldwell and Lyon Counties is also very uncertain as a whole in respect to type and classification, and to indicate the individuality, or rather lack of it, in the product of these counties it is sometimes designated as the Princeton and Eddyville type from the names of the chief market towns in these counties.

Detached from the general area in Tennessee, about Tallahoma as a center, in the southwestern portion of Coffee County, there is a small area which for about 10 years past has been producing a few hundred thousand pounds of dark tobacco annually, partly air cured and partly fire cured, which has generally moved to market through the Clarksville district. Clarksville and Springfield, Tenn., and Hopkinsville, Ky., are the principal market centers for this district. Adairville, Cadiz, and Guthrie, Ky., are other important local receiving points.

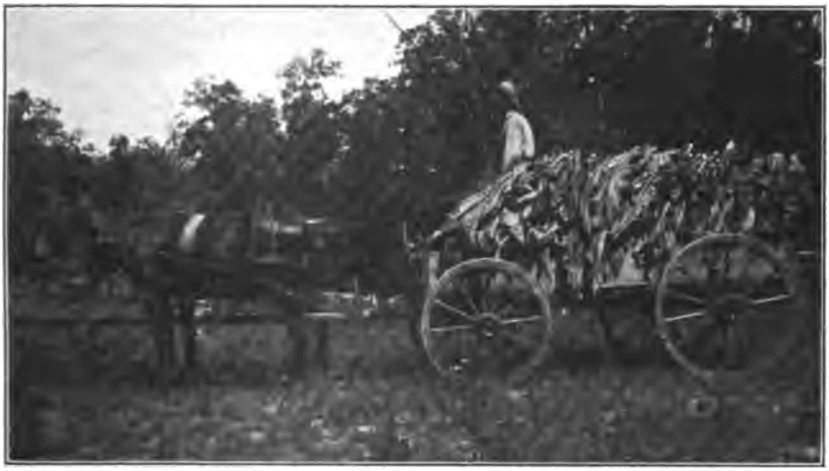

FIG. 18.—Hauling tobacco from the field to the curing barn, showing a common but careless method practiced in many sections as well as in the Paducah district, Graves County, Ky., where the photograph was taken.

THE PADUCAH DISTRICT.

The type of tobacco produced in the Paducah district of the western dark-fired section is not greatly different from that of the Clarksville and Hopkinsville district. The product as a whole is not quite as fine and rich as that of the Clarksville district.

Figure 18 shows a careless method which is altogether too commonly practiced in handling tobacco from the field to the curing barn.

The annual production of leaf tobacco in the Paducah district is about 60,000,000 pounds, about 45,000,000 pounds being produced in

Kentucky and 15,000,000 pounds in Tennessee. Graves County in Kentucky and Weakley County in Tennessee together produce nearly one-half of the entire crop of the Paducah district. The production is distributed, by counties, in Tennessee about as follows:

	Pounds.
Weakley	9,500,000
Henry	5,000,000
Obion	500,000
Total for the Paducah district in Tennessee	15,000,000

Detached from the main area of the Paducah district, a small section near Dyersburg, in Dyer County, produces some 200,000 or 300,000 pounds of tobacco of the Paducah type annually.

In Kentucky the production of the Paducah type of tobacco is distributed about as follows:

	Pounds.
Graves	15,000,000
Calloway	8,000,000
Ballard	7,000,000
Marshall	5,000,000
McCracken	3,500,000
Carlisle	3,500,000
Fulton	1,500,000
Hickman	1,000,000
Livingston	500,000
Total for the Paducah district in Kentucky	45,000,000

Paducah and Maysville, Ky., are the most important market towns for this district. Murray and Fulton, Ky., and Martin and Paris, Tenn., are also receiving centers of importance. The Paducah district is often spoken of as the "Western district," the terms being synonymous.

DISTRIBUTION IN USE OF THE COMBINED CLARKSVILLE AND HOPKINSVILLE AND THE PADUCAH TYPES.

The general character of the tobacco produced in the Clarksville and Hopkinsville district and in the Paducah district is substantially the same. The strong red clay subsoil is much more prevalent in the Clarksville and Hopkinsville district than in the Paducah district, which runs more to gray or yellow. Differences in soil naturally cause some differences in the character of the tobacco produced in the two districts. That from the Clarksville and Hopkinsville district is as a whole richer and darker as well as finer in texture than that from the Paducah district.

The really fine grades, such as plug wrappers either for domestic use or for export (principally to Canada), are obtained almost entirely from the Clarksville district, as are also the fine Austrian and Swiss types and the finer Italian grades.

But the fine grades are produced in relatively very small volume. The lighter bodied mottled types suited for the French and Belgian trade are found more largely in the Paducah district, while the fat, rich, German grades come largely from the Clarksville district, as do also the larger portions of the better bodied snuff types.

For the general purposes of this publication the two districts may best be considered as a whole in discussing the final distribution of their product. The general methods of cultivation, curing, handling, and marketing the tobacco produced in the two districts are almost identical. The combined Clarksville and Hopkinsville and the Paducah districts are often spoken of in local parlance as the "black patch."

A fair estimate of the average production of the combined "black-patch" district for the past five years is about 130,000,000 pounds of tobacco annually, 70,000,000 pounds in the Clarksville and Hopkinsville district and 60,000,000 pounds in the Paducah district. In 1910 the combined production was about 140,000,000 pounds and in 1903, with the largest crop on record, it was about 150,000,000 pounds. It has, however, in some years sunk considerably below these figures. An approximate average distribution of this product is estimated to be about as shown in Table X.

TABLE X.—*Estimated distribution in use of the tobacco produced in the Clarksville and Hopkinsville and the Paducah districts.*

Kind and place.	Proportionate distribution.	
	Per cent.	*Pounds.*
Plug wrappers	1	1,250,000
Austria	1½	2,000,000
Switzerland	1½	2,000,000
Italy	23	30,000,000
Snuff and miscellaneous domestic use	19½	25,250,000
Germany and Bremen	20	26,000,000
France	10	13,000,000
Spain	7½	10,000,000
Great Britain	7	9,000,000
African and rehandling	3½	4,500,000
Miscellaneous export, Belgium, etc	5½	7,000,000
Total	100	130,000,000

GRADES AND PRICES IN THE CLARKSVILLE AND PADUCAH DISTRICTS.

Since 1904 a considerable portion of the "black-patch" production has been pooled and sold through the agency of the Planters' Protective Association. The following schedule of prices fixed by the association for the sale of the 1908 crop is of interest in throwing light on the comparative value of the different grades into which the tobacco of this district is usually classed in reassorting after it gets into the hands of dealers, although the farmer usually finds it sufficient to assort his individual crop into only about three grades. In considering these prices it should be remembered that they represent figures considerably above the normal farm price. The grades established and prices set for the specified grades are shown in Table XI.

TABLE XI.—*Schedule of prices, by grades, set by the Planters' Protective Association for the sale of the pooled 1908 crop, representing over 50,000 hogsheads of the Clarksville and Hopkinsville and the Paducah types of leaf.*

Grades.	Price per 100 pounds.	Grades.	Price per 100 pounds.	Grades.	Price per 100 pounds.
Plug wrappers:		Spinning leaf:		French and Belgian:	
Fancy	$18.00	Fancy	$16.00	A's	$12.00
Fine	17.00	Fine	15.00	B's	9.50
Good	16.00	Good	13.50	B–C's	9.00
Medium	14.00	Medium	12.00	C's	8.50
Common	12.00	Common	10.50	C 2's	8.00
Austrian:		African:		Spanish:	
A's	17.00	Fancy	12.00	A's	10.00
B's	15.00	Fine	11.00	B's	9.50
B 2's	12.50	Good	10.00	C's	8.50
C's	12.00	Medium	9.50	Lugs:	
C 2's	11.00	Common	9.00	Fine	9.00
Italian:				Good	8.00
A's	15.00	Snuffers:		Medium	7.00
B's	14.00	Fine	12.00	Common	6.50
B 2's	13.00	Good	11.00	Low	6.00
C's	11.00	Medium	10.00	Trash	4.00–5.00
C 2's	9.50	Common	9.00		

THE HENDERSON OR "STEMMING" DISTRICT.

The Henderson subdivision of the dark-fired tobacco district produces a type of leaf particularly suited to the British trade. In the past a large proportion of it has been stemmed before shipment, which fact gave rise to the name "Stemming" as applied to the district. It is a rather coarse tobacco of large leaf, which makes it strip to advantage, and it has good absorptive capacity, which gives an opportunity for a considerable increase in weight after having passed the British customs as nearly as possible at the prescribed 10 per cent moisture basis. Figure 19 shows long and short English strips of the Henderson type.

The annual production of the "Stemming" district is approximately 35,000,000 pounds, distributed about as shown in Table XII.

TABLE XII.—*Estimated annual production of the Henderson or "Stemming" district, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.	Counties.	Pounds.
Henderson	10,000,000	Union	3,000,000	Muhlenberg	1,000,000
Webster	7,500,000	Caldwell	1,500,000		
Hopkins	6,000,000	Livingston	1,000,000	Total	35,000,000
Crittenden	4,000,000	Lyon	1,000,000		

About 50 per cent of the product of the district is handled through Henderson, which is the important market town of the district. Other important receiving points are Providence, Madisonville, Princeton, and Nebo.

The principal purchasers of this type of tobacco have large establishments for stemming and redrying the leaf or strips for export at Henderson and the other important market towns of the district. The quantity of tobacco stemmed before shipment has recently been reduced to a small proportion.

Probably 90 per cent of the entire product of this district goes to Great Britain, or about 30,000,000 pounds when the normal crop of 35,000,000 pounds is produced. The Italian Régie sometimes takes 2,000,000 or 3,000,000 pounds from this district, which, together with a miscellaneous foreign demand, might easily make up the remaining 5,000,000 pounds not taken by Great Britain.

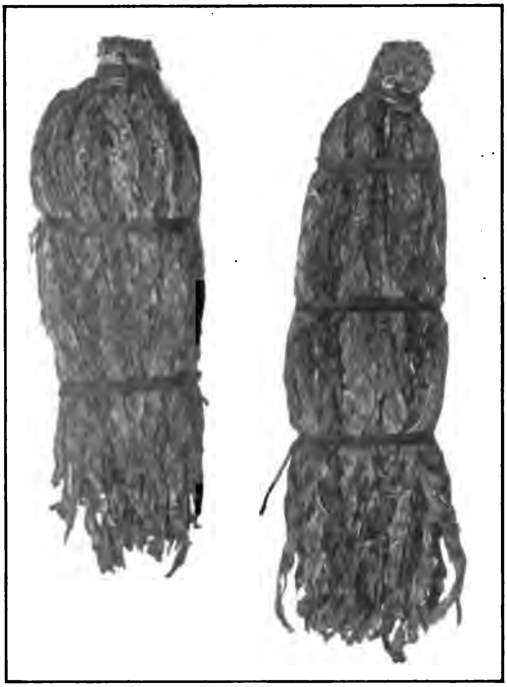

FIG. 19.—English strips, long and short, dark-fired tobacco, Henderson or "Stemming" district, Kentucky. (Photographed by the Bureau of Soils.)

The territory covered by the dark-fired districts of Virginia, Kentucky, and Tennessee, including their several subdivisions, is shown on the maps (Pls. I and II, in pocket).

THE MARYLAND OR BALTIMORE TYPES OF TOBACCO.

As already stated, the beginning of the production of tobacco in Maryland was almost coeval with the beginnings of its production in Virginia, and it is thus one of the oldest types produced in this country. In the early days practically all the tobacco produced was exported. Maryland, having a palatinate form of government and being to a large extent free from the domination of the British colonial policy, could ship tobacco to other than British ports. Much of the Maryland product, therefore, went direct to the Continent, particularly to Holland and France. The foreign demand for Maryland tobacco was thus established at a very early date and has persisted to the present time. The tobacco of the Maryland or

Baltimore types is nearly all exported, and France and Holland remain, as in the early days, the most regular, dependable, and important customers. The tobacco included under this head is the annual product of three districts, as follows:

	Pounds.
Southern Maryland	17,000,000
Upper-county Maryland or Bay	1,000,000
Eastern Ohio export	3,000,000
Approximate total	21,000,000

The tobacco of each of these three districts is marketed through Baltimore. The trade generally speaks of Maryland tobacco in terms of hogsheads, which average about 700 pounds net weight each. The average annual production of the three districts amounts to not far from 30,000 hogsheads. About 90 per cent of this tobacco is exported and 10 per cent used in domestic consumption.

In domestic consumption Maryland tobacco is used to some extent in the manufacture of low-grade cigars, the quantity utilized for this purpose varying considerably each year, depending upon the relation between the prices of tobacco of these types and of the regular cigar types. In the last few years also, owing to the high price of Burley, there has been a considerable increase in the quantity of the Baltimore types taken for domestic consumption to substitute for Burley, particularly from the upper-county and eastern Ohio grades where Burley seed is quite generally used.

DISTRIBUTION IN USE.

A good idea of the market distribution of Maryland tobacco may be had from the annual trade review of the Baltimore tobacco market issued by Van Kapff & Arens, under date of January 3, 1910, covering the previous year's transactions, an extract from which is shown in Table XIII.

TABLE XIII.—*Distribution of Maryland and (eastern) Ohio tobacco in 1909.*

Where distributed.	Hogsheads.	Where distributed.	Hogsheads.
France	10,316	Italy	125
Holland	11,792	England and North Europe	91
Bremen	1,330	Home consumption	4,243
Hamburg	1,141		
Antwerp	848	Total	29,886

Much the larger portion of these Baltimore types of tobacco is air-cured. All of the southern Maryland type is air-cured, which is in itself nearly 80 per cent of the total, and in late years all but a very small proportion of the upper-county product has been also air-cured. Originally this upper-county tobacco, generally spoken of as Bay tobacco, was nearly all cured by open fires in rather small, tightly daubed log barns. The cured product, therefore, had a characteristic smoky odor and flavor similar to the dark-fired tobacco of Virginia, Kentucky, and Tennessee. The resemblance ceased here, however, as this Bay tobacco, as well as that of southern Maryland and eastern Ohio, was characteristically light in color and body and deficient in strength and richness, as the dark-fired was characteristically heavy in body, dark in color, and very rich in so-called oil and gum. In earlier years the southern Maryland tobacco was, to a considerable extent, cured or at least dried out by open fires, but the practice there has been abandoned. A characteristic southern Maryland curing barn is shown in figure 20. A sample of Maryland colory leaf export tobacco is shown in figure 21.

The eastern Ohio tobacco district was settled in the years succeeding the Revolutionary War, principally by pioneers from Maryland, who carried the production of tobacco with them just as the pioneers from Virginia and North Carolina carried the production into Kentucky and Tennessee. Naturally they carried the seed and methods of producing tobacco in Maryland with them and they continued to market the tobacco through Baltimore, the market with which they were most familiar and where the type of tobacco which was thus produced could be marketed to the best advantage.

Eastern Ohio tobacco is often spoken of as spangled tobacco from its characteristic of curing up in blotched areas over the leaf, changing sharply from a clear straw yellow to a clear brown or red, that is, it is a two-colored tobacco. The yellow colors are most desired and bring the highest prices. The tobacco is classed as yellow spangled when the much-desired clear yellow color predominates and as red spangled when the red predominates.

Eastern Ohio tobacco is typically a fire-cured tobacco, but flues made of loosely laid-up stones are generally used instead of building open fires on the ground within the barn. In this way the fires are made and kept up from the outside, but the smoke escapes inside, giving the tobacco a smoky or creosotic odor and flavor. In later years sheet-iron flues have been substituted for the rock flues to some extent and the process of curing is similar to the method pursued in the bright belt of eastern North Carolina and South Carolina. As in the new section of the bright belt also, the crop is harvested by picking the leaves from the stalks as they ripen in the field, but they are strung with a needle and string and placed on a scaffold outside the barn for a day or two to yellow before being placed in the barn and the fires started. As an aid in producing brighter colors, the eastern Ohio growers plant the tobacco very thickly, about 10,000 plants to the acre, and top very high, or often not at all, so that at harvest time the tobacco field is a veritable flower garden of seed heads in bloom.

Rather high topping and close planting is resorted to in the Maryland tobacco districts proper in order to keep the colors brighter, but not to the same extent as in the eastern Ohio district. In Maryland, moreover, the entire plant is harvested and cured, being severed close to the ground and speared on the sticks about as practiced in most of the cigar-tobacco districts. In recent years the proportion of air-cured tobacco produced in eastern Ohio has increased greatly, owing particularly to the scarcity and high price of Burley, and more than half of the crop is now air cured and moves to market not through Baltimore, but through Cincinnati or Louisville. The fire-cured portion of the crop, however, continues to be sold in Baltimore and during the past few years has ranged from 2,000 to 6,000 hogsheads a year.

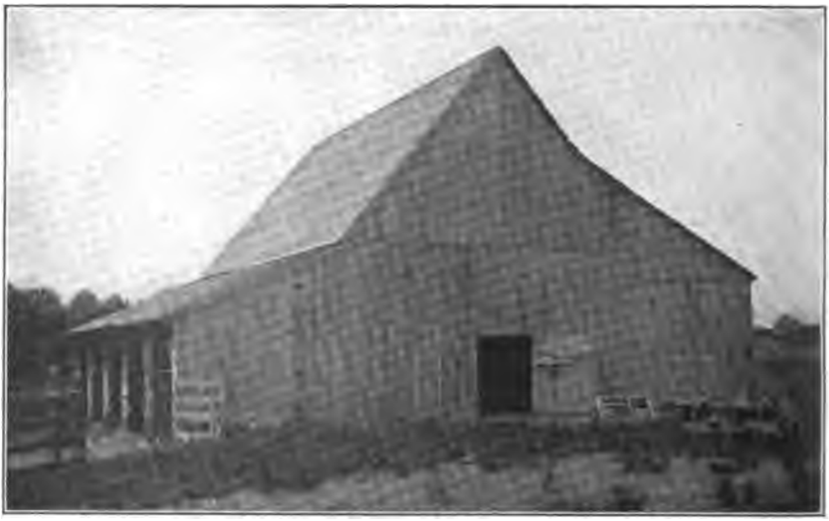

FIG. 20.—Maryland tobacco-curing barn, Upper Marlboro, Prince Georges Co., Md.

The production of all these Baltimore types of tobacco has tended in later years to decrease rather than to increase, and the output now ranges considerably below the maximum attained in the periods just before and just succeeding the Civil War. In the seventies Maryland proper produced annually from 35,000 to 40,000 hogsheads, instead of 25,000 as at present, and eastern Ohio produced 15,000 to 20,000 hogsheads, instead of 4,000 as at present. In 1874 the eastern Ohio production marketed through Baltimore, which included practically all of it, was 28,000 hogsheads. The cause of this decrease in production has not been due to actually lower prices on the average, but rather to an increasing cost of production and to the diversion of attention to other crops which have proved more profitable. In the eastern Ohio section, the development of the petroleum industry also proved a diverting influence, as lands were more valuable for oil wells than for farming.

The Baltimore types of tobacco are valuable as a whole because of their color, good burning qualities, and fineness. For these qualities they are desired by European countries, where they are much used to mix with other tobacco to make the appearance of the latter more attractive and to help the combustion of bad-burning tobaccos. Aside from these qualities, the Baltimore types are rather weak, dry, and characterless tobaccos. They are used almost exclusively for pipe smoking and for cigarettes.

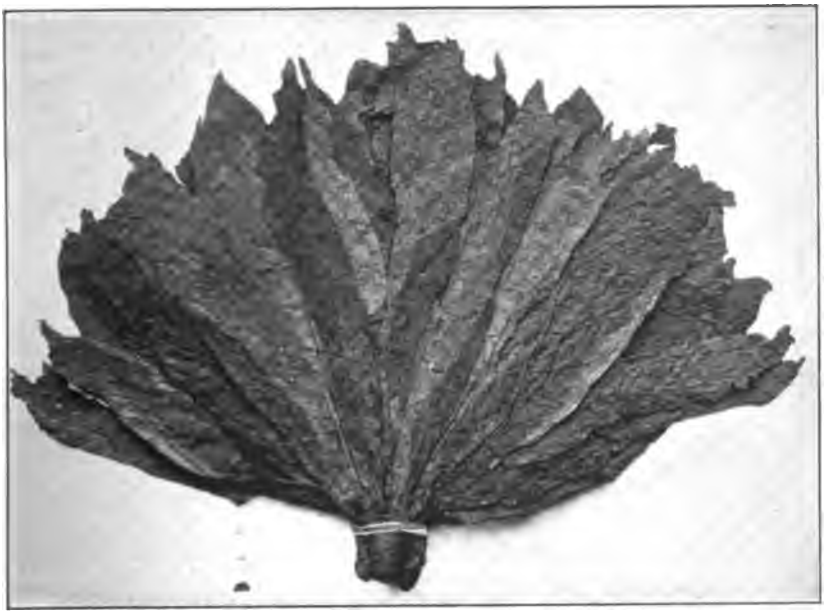

FIG. 21.—Maryland fine colory leaf export tobacco, showing how hands are fanned out in packing. (Photographed by the Bureau of Soils.)

In general appearance the Maryland tobacco more nearly resembles Burley than any other important type, both in color and in general appearance, but it does not possess such good absorptive capacity for sauces or other liquids, and has not quite as good life and body. Indeed, Burley seed is used extensively both in the upper-county Maryland district and in the eastern Ohio district.

Until recently about 10 per cent of the eastern Ohio tobacco was produced across the river in West Virginia, particularly in Jackson and Wood Counties. Recently, however, the production of the fired, spangled tobacco in West Virginia has been greatly reduced and the tobacco now produced there is nearly all ordinary air-cured Burley.

GRADES AND PRICES.

The Maryland types of tobacco as a whole are produced on rather light soils, ranging from loamy clays to those that are quite sandy. They are very easy to work. Most colory tobaccos are produced on the lighter class of soils. Holland takes most of the highest colored tobacco and pays the best price, sometimes as high as 15 or 16 cents a pound for the air-cured types. The best fired bay and spangled tobaccos often bring from 18 to 20 cents or more a pound and go principally to brokers in the open markets of Germany (Bremen and Hamburg) for final distribution to the manufacturers of northern Europe. France takes more of the red grades.

The general average price for Maryland tobacco has been about 5½ to 6½ cents a pound. The last few crops, however, owing to the generally higher price level for all tobaccos, have commanded a somewhat better price, the Baltimore market averaging about 7 cents in 1908 and a little better than that in 1909. Under this influence the acreage in Maryland has shown a tendency to expand, but scarcity of labor and higher prices for other products as well have been offsetting factors.

DISTRIBUTION OF ACREAGE.

The Maryland tobacco crop proper is produced entirely in the five southern counties of the State, mostly south of a line connecting Baltimore and Washington, D. C., including the peninsula between Chesapeake Bay and the Potomac River. Table XIV shows the approximate distribution of the annual production.

TABLE XIV.—*Estimated annual production of the Baltimore types of tobacco, distributed in the 5 counties.*

Counties.	Pounds.	Counties.	Pounds.
Prince Georges	4,500,000	Calvert	3,250,000
Charles	3,500,000	Anne Arundel	2,500,000
St. Marys	3,250,000	Total	17,000,000

The larger portion of Maryland tobacco is marketed in the summer and fall of the year following that in which it is grown. It is shipped in hogsheads to a considerable extent by water from the numerous wharves on the rivers and inlets abounding on both the Chesapeake and Potomac side of the peninsula. Maryland tobacco is not redried prior to shipment abroad after being purchased from the farmers, and it is therefore necessary that the tobacco have some age and be thoroughly dried out and conditioned before it is marketed. It is generally exported in the original hogsheads as sent in by the farmers.

It is common to see on the roads of southern Maryland a load consisting of one or two hogsheads of tobacco drawn by oxen or horses, as shown in figure 22.

Upper-county or bay tobacco is produced principally in the central and northern part of Montgomery County, the area extending, however, into Howard, Carroll, and Frederick Counties. The production of this section amounts to nearly 1,000,000 pounds yearly. Mount Airy is the most important shipping point for this district.

The eastern Ohio export district includes portions or all of Belmont, Guernsey, Noble, Monroe, and Washington Counties. The proportion of fired tobacco is much greater in the northern portion of the area. In the southern portion the percentage of regular air-cured Burley is large. The principal point for shipping the export tobacco is Barnesville, in Belmont County. Several firms there buy leaf from the farmers, usually at a round price, and then grade and condition the tobacco for shipment to Baltimore commission houses, which effect the final sale to the exporter.

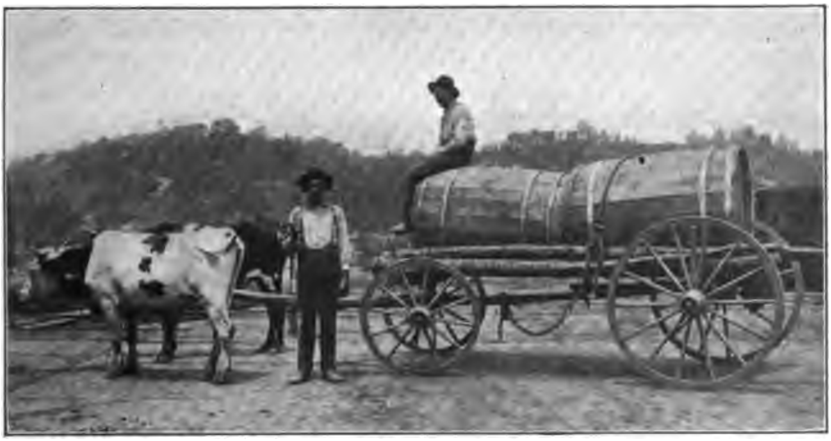

FIG. 22.—Hauling prized tobacco to railroad station for shipment. A scene particularly common in portions of the Burley district, in the Maryland tobacco district, and where farmers prize and ship in hogsheads.

The approximate outlines of the Maryland tobacco districts and the eastern Ohio export district are respectively shown on Plates I and II (in pocket).

FLUE-CURED TOBACCO.

ORIGIN AND EARLY DEVELOPMENT.

Flue-cured tobacco, as it is known to-day, is essentially a modern type. Its development has taken place principally since the Civil War and its most rapid development, particularly in the New Belt section of eastern North Carolina and South Carolina, has been since 1890. Its maximum production was reached in 1903, when the flue-cured crop exceeded 250,000,000 pounds, according to estimates of competent members of the tobacco trade based on market reports.

Although a modern type in its present development, flue-cured tobacco was in its origin closely associated with the old Virginia dark type and is a development and offshoot from it, dependent upon soil modification and trade preferences. As the cultivation of tobacco in Virginia was pushed back upon the poorer sandy lands of the southern tier of counties of the State, the character of leaf produced was naturally modified, particularly in color and mildness. It became very popular for home manufacture and consumption, particularly in the shape of plug for chewing purposes. To make it more acceptable for this purpose the use of open fires in curing was limited as much as possible, and much of the product of this sandy type of soil was merely air cured, fires being used only to protect it from damage in bad weather. In order to keep down the odor of smoke, charcoal was often substituted for wood. The use of charcoal for curing finally became a regular practice, until superseded by the use of rock flues and finally by sheet-iron flues, which still further did away with any tendency to smokiness and gave more satisfactory results, particularly in obtaining brighter and more uniform colors and greater economy of fuel and convenience in firing.

Under the perfected flue system of curing it is possible, with tobacco produced on certain soil types, to make beautiful and uniform curings of a very bright, clear, straw, or lemon yellow color with hardly a vestige of brown or green shade, the stem often being as bright and clear as the leaf itself.

On the right soils, moreover, these flue-cured types often possess good life and body and fineness of fiber, and it is this combination of color, body, and fineness, with medium to good size of leaf as a necessary secondary qualification, usually not difficult to obtain, that constitutes the fancy grades of the flue-cured type that bring farm prices ranging from 20 cents up to 40 or 50 cents a pound.

The following story of the evolution of "yellow" tobacco is obtained from an account written many years ago by the late Maj. R. L. Ragland, of Halifax County, Va., himself a noted grower and a well-posted man regarding the tobacco industry. He states that particular attention was first attracted to the light-colored piebald or mottled tobacco of Virginia and North Carolina soon after the War of 1812 to meet an export demand for such types from France, and that in the export trade the type was called "French" tobacco. Furthermore, the domestic manufacture of tobacco (principally plug) began to expand about this time and these mild, light types also came into greater demand for that purpose. Planters with suitable soils, particularly freshly cleared fields of a gray or sandy nature so common in the border counties of central Virginia and North Carolina between the coastal plain and the Blue Ridge, vied with each other in producing the highest colored sweet and mild tobaccos.

The method of curing first in use was to begin with small open fires to be continued until the leaf was properly yellowed and then increase the fires steadily and cure up the leaf as yellow as possible with open wood fires. Maj. Ragland thought that charcoal was first made use of in curing this type about 1824 in Caswell County, N. C., the honor lying between Capt. Abishai Slade and Mr. William Long. Maj Ragland also states that Dr. Davis G. Tuck, of Halifax County, Va. was the first to use flues in curing tobacco and was granted a patent therefor in 1829. Because of the defective plan of construction, however, these flues were very liable to burst in use, and they never came into general use until about the time of the Civil War and after the plan of construction had been improved.

Maj. Ragland speaks also of attending a meeting of tobacco growers in 1850 at Cluster Springs, Halifax Co., Va., to listen to an address by Capt. Slade on coal curing yellow tobacco. Up to 1850 the production of yellow tobacco was small and confined principally to Caswell County, N. C., and Pittsylvania County, Va.

Figure 23 shows a typical field of tobacco of the fine flue-cured type grown on freshly cleared land, which generally yields the brightest and finest textured leaf. Figure 24 shows a standard type of flue-curing barn which has been in use in the Old Belt section.

IMPORTANCE OF FERTILIZERS IN STIMULATING PRODUCTION.

An important factor in making the rapid development in production of the flue-cured type possible since the Civil War was the introduction of commercial fertilizers.

Bright tobacco soils as a class are naturally rather infertile. Before the use of artificial manures became general in the seventies of the last century the portion of the country now noted for the production of the fine flue-cured leaf was but little farmed. On most of these soils crop yields including those of tobacco were so small without fertilizer that it did not pay to cultivate them. They were, however, light and friable and of a character to respond readily to fertilizers, particularly in producing a high-value crop like tobacco. The use of fertilizers increased the chances of profit from growing tobacco in two ways. It markedly increased the yield, often more than 100 per cent, and also improved the quality greatly, so that the tobacco would sell for a higher price per pound. Many soils which with fertilizers would produce a good yield of fine tobacco at a satisfactory profit would produce almost nothing without them. The use of fertilizers was, therefore, a most potent factor in rendering possible the

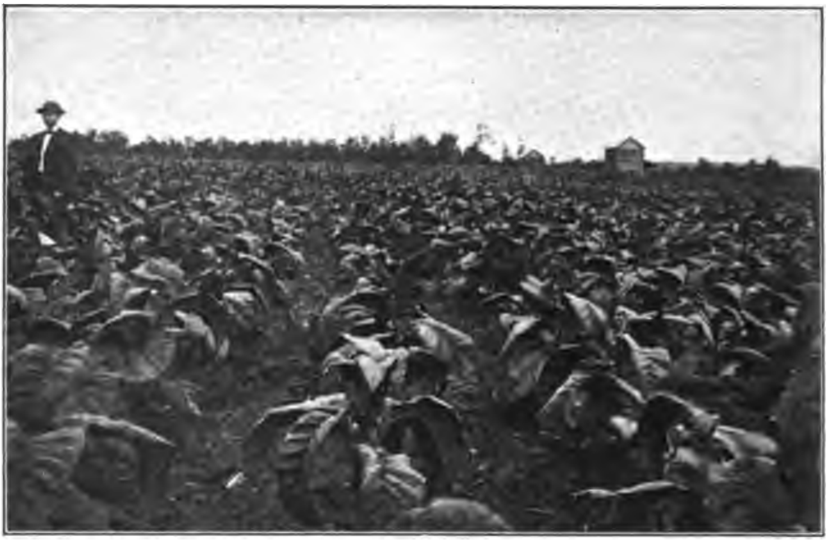

FIG. 23.—Field of "fresh land" tobacco of the flue-cured type in the Old Belt district, Pittsylvania County, Va.

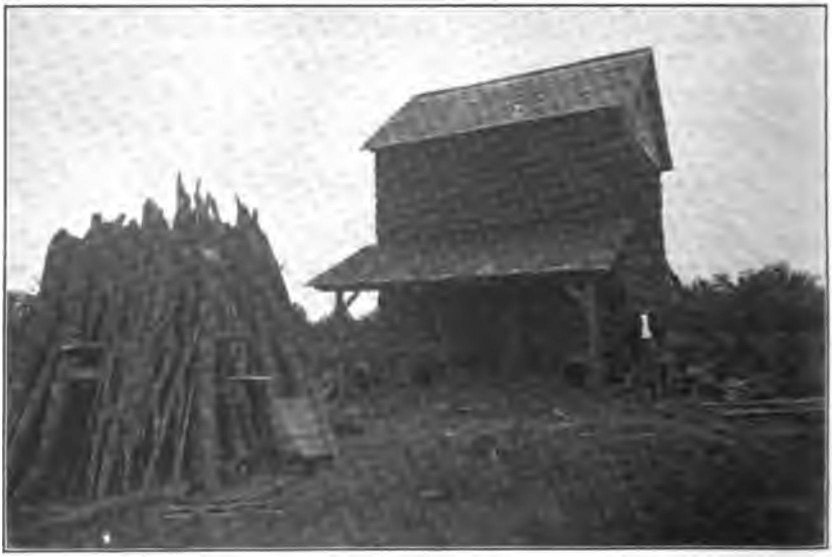

FIG. 24.—Typical flue-curing tobacco barn, Old Belt section, Pittsylvania County, Va. The pile of wood is for burning in the furnaces.

great development in the production of bright flue-cured tobacco. There are to-day no other types of tobacco on which fertilizers are so freely used as on the bright flue-cured types, except on some of the high-priced cigar-wrapper types in New England and Florida.

USES OF FLUE-CURED TOBACCO.

DOMESTIC CONSUMPTION.

In the early days, before the Civil War and soon after, the forerunner of the present flue-cured type was principally an air or "coal" cured product. It was mostly red, mahogany, or piebald in color and was manufactured largely into domestic plug for chewing. It was very acceptable for this purpose and made a mild, sweet, aromatic chew.

The manufactures of this type of plug had not then developed the present system of brands nor was it so concentrated in a few large factories as at present, and the business was divided up among a comparatively large number of independent factories in the larger towns scattered throughout the growing districts.

The product of these factories was distributed largely by wagons, which would make long trips into nonproducing sections, peddling out the manufactured product at the crossroad stores. On the return trip these wagons would pick up such merchandise as might be handled to advantage in the home town. Petersburg, Lynchburg, Farmville, Clarksville, South Boston, Danville, and Bedford City were among the more noted of these local centers for the manufacture of plug chewing tobacco; but the business of nearly all of these towns in this class of tobacco has diminished greatly under modern conditions, and some of them are now almost completely out of the tobacco-manufacturing business.

The primary cause which has led to the decadence of these local independent factories is the concentration of manufacturing in the hands of a few large firms with large city factories.

The business of manufacturing flue-cured plug, generally known as flat plug to distinguish it from the thicker, more heavily sweetened Burley plug made in the West, is now largely concentrated in Winston Salem, N. C., where the manufacture of tobacco has had a very rapid development. The industry was in its infancy in the early seventies of the last century. The quantity manufactured now amounts to upward of 40,000,000 pounds of tobacco annually and in gross output Winston ranks second only to St. Louis, Mo., among the great manufacturing centers of the country. A few million pounds of flue-cured plug are also manufactured at Reidsville, N. C., and at Martinsville, Va.

The manufacture of this class of plug is still one of the most important uses of flue-cured tobacco. The grade of tobacco used for this purpose is the heavier bodied, thoroughly ripened, red and mahogany filler leaf produced principally in the western portion of the flue-cured belt in the Piedmont section of Virginia and North Carolina.

Figure 25 shows chewing leaf, plug, and twist tobaccos in various stages of manufacture. Flue-cured tobacco and bright tobacco are often spoken of as being synonymous. Much flue-cured tobacco, however, particularly that best suited for plug filler, as grown in the western portion of the Old Belt known as the Winston-Salem and Martinsville district, can at best be classed as no more than semi-bright, and much of it is red or dark mahogany.

Another important use to which flue-cured tobacco is put is in the manufacture of granulated smoking tobacco, which, in fact, probably utilizes a greater number of pounds of this type of leaf than any other single use. On the market the leaf suitable for granulating is generally spoken of as "smokers" and consists principally of the light-bodied, "poor" leaf and scrap obtained from the bottom of the plant. It is obtained from all portions of the flue-cured district.

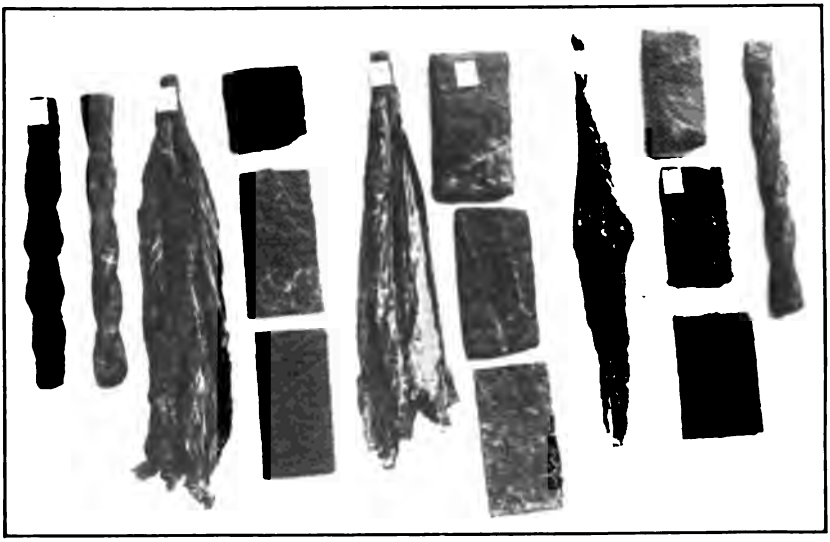

FIG. 25.—Stages in the manufacture of chewing, twist, and plug tobaccos. (Photographed by the Bureau of Soils.)

The great center for the manufacture of granulated smoking tobacco is Durham, N. C. The output of granulated smoking tobacco in Durham is more than 30,000,000 pounds annually.

The extensive use of this granulated form of smoking tobacco has developed almost entirely since the Civil War, and this fact, together with the nearly simultaneous development of the machine-made cigarette, in a great measure accounts for the rapid spread of the production of the flue-cured type of tobacco. In the early days the tobacco was granulated or flaked by means of flails or sticks, now of course superseded by special granulating machinery.

Flue-cured tobacco is also used extensively in the production of machine-made cigarettes and is the most important type of tobacco for this purpose produced in the United States. The cigarette grades, generally designated as cigarette cutters, are ranked among the better grades of leaf. They must be sound and must possess good life and oil as well as good color and fineness of fiber, but do not need to possess quite the body and toughness necessary in a plug wrapper.

This district also produces a large percentage of the leaf used in wrapping plug, both of the flat Winston Salem type and of the western type made from heavily sweetened Burley. These plug wrappers constitute the highest grades of flue-cured tobacco and bring from 25 to 50 cents a pound, according to the supply and to the body fineness and color of the leaf itself. The middle section of the flue-cured district from Henderson, N. C., to Danville, Va., produces the largest percentage of leaf suited for plug wrappers. Specially noted sections producing a high grade of wrapper leaf are the Dutchville district of Granville County, N. C., and the White Oak Mountain district of Pittsylvania and Halifax Counties, Va. About 60 per cent of the total flue-cured crop is used in domestic consumption.

EXPORT DEMAND.

While the flue-cured type of tobacco is particularly adapted for manufacture and use in domestic consumption and is most extensively used at home, it is, nevertheless, also a favorite export type, with a constantly expanding foreign market. It is about the only type of tobacco produced in this country which has tended in recent years to decidedly increase the volume of our exports of leaf tobacco. This export trade would probably increase more rapidly were it not for the sharp competition of domestic demand, resulting in relatively high prices as compared with the other export types.

Great Britain and the British possessions, Canada, South Africa, and Australasia, are by far the most important foreign customers for this type of tobacco. These countries use it principally for smoking tobacco and cigarettes. China, Japan, and some of the European countries also make use of this type in considerable quantities.

The trade reports of the principal markets of Great Britain indicate that that country alone takes from 45,000,000 to 50,000,000 pounds of our flue-cured type of leaf annually.

In the foreign trade flue-cured tobacco is often spoken of as Virginia leaf or strips, probably because in the past, as is also still largely true, it was exported in great part through the markets of Virginia, particularly Richmond and Danville, although, of course, North

Carolina produces far more flue-cured leaf than does Virginia, as indicated in Table XVII (p. 68). Figure 26 shows an interior view of a leaf factory at Greenville, N. C., engaged in the making of strips for export to England.

DISTRIBUTION IN USE.

Estimating the total average production of flue-cured tobacco in the Old Belt and in the New Belt at about 215,000,000 pounds annually, it would be interesting to know how this tobacco is distributed in the trade according to the uses to which it is put. No figures can be quoted giving this information in an accurate statistical way. However, making use of revenue returns, export figures, trade reports, and of general information picked up here and there, the following estimate of distribution may be accepted as substantially correct:

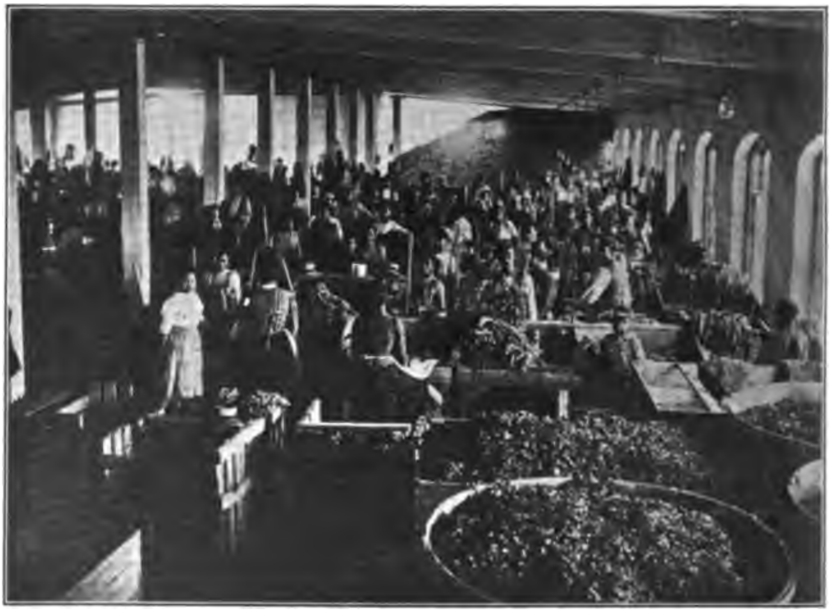

FIG. 26.—Stemming room of a leaf-tobacco factory, Greenville, N. C. New Belt flue-cured type of leaf. (Photographed by the Bureau of Soils.)

TABLE XV.—*Estimated distribution in use of flue-cured tobacco.*

Kind and location.	Pounds.
Domestic use:	
Granulating	55,000,000
Plug filler and cut plug	37,000,000
Cigarette cutters	25,000,000
Plug wrappers	10,000,000
Total	127,000,000
Export:	
Great Britain	48,000,000
Canada	10,000,000
Export—Continued.	
Australasia	8,000,000
China	10,000,000
Japan	2,000,000
Miscellaneous (Europe, South Africa, etc.)	10,000,000
Total	88,000,000
Grand total	215,000,000

GRADES AND PRICES.

At 10 cents a pound, which is about the average for the five years ending in 1910, the flue-cured type of tobacco has brought to growers the sum of about $20,000,000 annually. Growers claim, however, that counting all factors in connection with the expense of producing flue-cured tobacco, it costs about 10 cents a pound to raise it.

The price schedule put forth by the Interstate Tobacco Growers' Protective Association of Virginia and North Carolina, given in Table XVI, throws some light on the various market grades into which the flue-cured type of tobacco is divided and the approximate relative prices of each. It should be borne in mind, however, that they are based upon a price level to the farmer fully 2½ cents a pound above that which has been current in recent years.

TABLE XVI.—*Scale of prices adopted by the Interstate Tobacco Growers' Protective Association of Virginia and North Carolina for the sale of their pooled holdings of flue-cured tobacco in October, 1904.*

Grades.	Price per 100 pounds.	Grades.	Price per 100 pounds.	Grades.	Price per 100 pounds.
Lemon wrappers:		Mahogany fillers:		Cutters (cigarette):	
Fine	$65.00	Fine	$22.50	Fine	$35.00
Good	50.00	Good	18.00	Good	30.00
Medium	35.00	Medium	15.00	Medium	22.50
Common	25.00	Common	10.00	Common	18.00
Orange wrappers:		Dark red fillers:		Bright smokers:	
Fine	60.00	Fine	16.00	Fine	18.00
Good	50.00	Good	14.00	Good	15.00
Medium	35.00	Medium	12.50	Medium	12.50
Common	20.00	Common	10.00	Common	10.00
Bright mahogany wrappers:		Dark fillers:		Heavy smokers:	
		Fine	16.00	Fine	16.00
Fine	55.00	Good	12.50	Good	14.00
Good	40.00	Medium	10.00	Medium	12.00
Medium	30.00	Common	8.00	Common	10.00
Common	18.00	Tips:		Lug fillers:	
Dark mahogany wrappers:		Bright	12.50	Fine	16.00
		Dark	9.00	Good	14.00
Fine	40.00			Medium	12.50
Good	25.00	Green	6.00 to 8.00	Common	10.00
Medium	22.50			Trash:	
Common	18.06	Export leaf (bright):		Low grades and trash	5.00 to 9.00
Bright fillers:		Fine	35.00		
Fine	20.00	Good	30.00		
Good	17.00	Medium	22.50		
Medium	15.00	Common	18.00		
Common	10.00				

FLUE-CURED TOBACCO AT THE PARIS EXPOSITION OF 1900.

At the Paris Exposition of 1900 our flue-cured bright leaf was considered by the jury of awards in comparison particularly with Turkish leaf, which is generally regarded as a distinctly cigarette type of tobacco. Mr. M. L. Floyd, the only member of this jury from the United States, reported that the jury was inclined to favor the Turkish leaf from the standpoint of quality. The bright, flue-cured leaf, however, is yet of very satisfactory quality even as a cigarette tobacco, and in addition it is susceptible of a much broader field of usefulness. Because of this much greater all-round usefulness and adaptability, the jury finally gave it the same award as the Turkish leaf, ranking them on an equal basis of merit and both were granted gold medals.

SUBDIVISIONS OF THE FLUE-CURED DISTRICT.

Broadly speaking, two quite well-defined subdivisions of producing area, reflected in a material modification in the general character of the tobacco produced, are recognized in the flue-cured territory, extending as it does from the piedmont and even the mountain section of western North Carolina and eastern Tennessee to the coast country of eastern North Carolina and South Carolina.

Up to the late eighties of the last century flue-cured tobacco was not produced in commercial quantities of importance east of Warren, Franklin, and Wake Counties in North Carolina, and the easternmost market town of importance for the sale of leaf tobacco was Henderson, N. C.

It was, however, grown even farther westward in the mountain section than at present. In the eighties of the last century the production of flue-cured tobacco had a considerable boom in some of the counties of east Tennessee and in the southern part of West Virginia. Buncombe and Madison Counties, N. C., were then quite heavy producing counties and Asheville and Marshall in these two counties, respectively, were important leaf markets. Greenville and Bristol, across the State line in Tennessee, also developed into market points of considerable importance.

The production of flue-cured tobacco has long since been abandoned in West Virginia and Burley now holds sway there. But little tobacco is now produced in the extremely hilly counties of western North Carolina, and Asheville and Marshall are no longer leaf markets.

In Greene County, Tenn., however, a considerable interest in tobacco growing still persists and the production has been something like 1,000,000 pounds annually for some years. In 1908 and since then, owing to the extremely high prices of Burley, the total tobacco acreage in eastern Tennessee subsidiary to Greenville as a market center has greatly increased. The estimated production in 1909 was from 3,000,000 to 5,000,000 pounds, less than half a million of which, however, was estimated to be of the flue-cured type, the interest having shifted to Burley. Bristol, which in its best years sold about 5,000,000 pounds of tobacco, has long since ceased to be a market.

All of the present flue-cured territory in Virginia and in western and central North Carolina to and including the counties of Warren, Franklin, and most of Wake is generally known among tobacco people as the "Old Belt" section. The line is of course more or less arbitrary, but it quite closely represents the approximate eastern limits of tobacco growing prior to the great expansion eastward which took place from 1885 to 1890, and also represents in broad outline the approximate division point between the New Belt and the Old Belt tobaccos in point of quality.

The Coastal Plain sandy soils of the New Belt section produce a brighter type of leaf, but generally with less body and substance than do the soils of the Old Belt with their greater percentage of clay, particularly in the subsoil.

Modifications in methods of cultivation and handling in the two regions are characteristic, particularly in the matter of priming, topping, harvesting, and curing. In the Old Belt section the plants are topped lower and generally a few bottom leaves are primed off and discarded at topping time, usually leaving only about 10 leaves to each plant to mature. In the New Belt section higher topping is practiced, that is, more leaves are left on the plant. In the Old Belt also, the whole plant is cut and cured at one time while in the New Belt it is customary to pick the leaves a few at a time as they ripen, beginning at the bottom of the plant and going up. Other modifications of method might also easily be noted in the two sections. Figure 27 shows the method of harvesting tobacco in the Old Belt section, the whole plant being harvested and hung on the stick, while figure 28 shows a harvesting scene in the New Belt section. The separate leaves are harvested and fastened to the sticks in small bundles with strings.

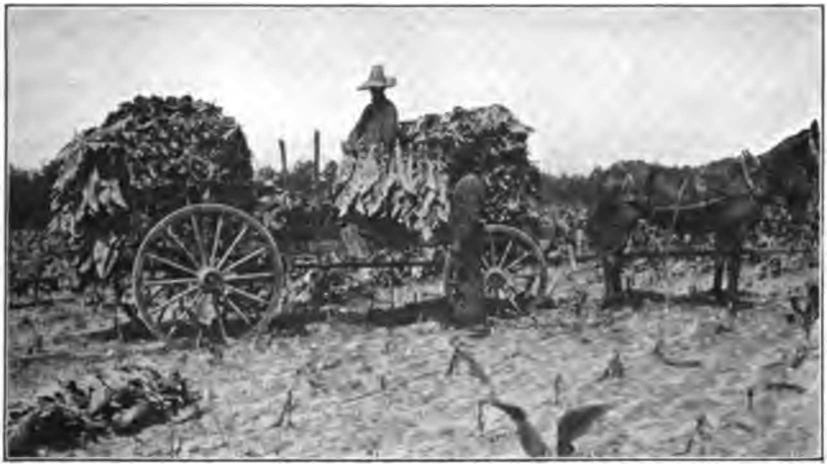

FIG. 27.—Common method of hauling tobacco from the field in the Virginia tobacco districts.

A number of reasons conspired to bring about the rapid introduction and extension of tobacco growing into eastern North Carolina and South Carolina in the last decade of the nineteenth century. Among these reasons the low price of cotton is noteworthy. The entire New Belt section is a cotton-producing country and any decided shifting in the balance between the price of cotton and tobacco is quickly reflected in the acreage and production of tobacco. The production of New Belt tobacco from year to year is therefore subject to extreme fluctuations amounting to doubling the crop in some instances and halving it in others. In 1903, when the maximum of production was reached in the New Belt, the crop was estimated at over 125,000,000 pounds; in 1904, under the influence of very low prices for tobacco and high prices for cotton, it was less than 60,000,000 pounds.

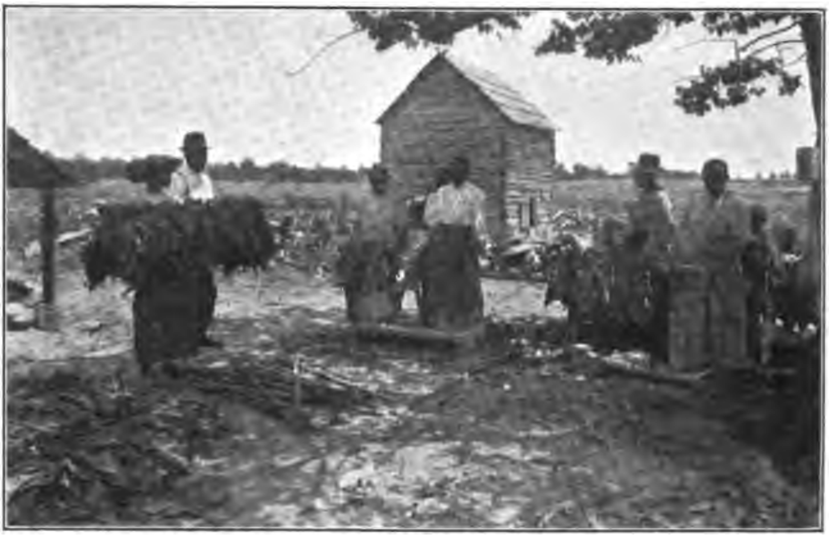

FIG. 28.—Stringing the leaves of tobacco of the flue-cured type in the New Belt section near Greenville, Pitt Co., N. C.

Cotton is not grown to any considerable extent, however, in the Old Belt section and the tobacco crop, therefore, is very much more uniform from year to year in regard to acreage, as no other money crop is available to which the acreage can readily be shifted. Although the Old Belt crop of 1903 was also large, amounting to about 125,000,000 pounds with correspondingly low prices, the crop of 1904 was only about 10,000,000 pounds less than in 1903.

Although the New Belt crop of tobacco exceeded that of the Old Belt in 1903, it is normally about 25,000,000 pounds a year less than the Old Belt. The normal production of the Old Belt district at the present time stated in round numbers is about 120,000,000 pounds, and that of the New Belt is about 95,000,000 pounds, making 215,000,000 pounds as the total annual production of tobacco of the flue-cured type.

Other important contributory causes for the rapid expansion of tobacco growing into the New Belt section in the decade mentioned was the rapid development and expansion in the demand for and consumption of granulated smoking tobacco and in the use of cigarettes, also the rapidly expanding foreign demand resulting in good prices for this type of leaf. This combination, therefore, of low prices for cotton and high prices for tobacco is the most important contributory cause of the rapid development of tobacco growing in the New Belt section.

A comparison of the census returns of 1890 with those of 1900 for the New Belt section of eastern North Carolina and South Carolina strikingly illustrates the rapid extension of tobacco growing in that decade. In 1890 the total production of the counties reporting tobacco in eastern North Carolina and South Carolina was 1,604,304 pounds, of which 1,381,406 pounds were in eastern North Carolina and 222,898 pounds in South Carolina. Of the total eastern North Carolina production more than half, 782,713 pounds, was produced in Nash County directly bordering the section designated as the Old Belt. Only two other counties in this section produced more than 100,000 pounds of tobacco each. They were Wilson and Wayne Counties with 232,966 and 112,010 pounds production, respectively.

The figures for the 1900 census show an amazing increase in this section. From less than 2,000,000 pounds total production of tobacco shown by the 1890 census, the figures for 1900 gave the New Belt section a production of 79,603,610 pounds, of which 59,707,640 pounds were produced in eastern North Carolina and 19,895,970 pounds in South Carolina. This great extension in production carried North Carolina ahead of Virginia and made it second only to Kentucky in total production of tobacco, which relative position the State has since continued to hold.

The maps (Pls. I and II, in pocket) show the approximate limits of the established producing territory for the flue-cured type of tobacco in 1909. The line separating the flue-cured type from the dark-fired type in Virginia is of course only an approximation. No definite line exists showing where one begins and the other ends. What really exists is a belt of country upon which can be found either type here and there, according to the character of the soil and the preference of the grower.

THE OLD BELT SECTION.

Table XVII gives a list of the counties in the Old Belt section of Virginia, North Carolina, and Tennessee that produce tobacco in important commercial quantities, with an estimate of the quantity produced in each. Counties like Mecklenburg and Charlotte in Virginia produce considerable quantities of both the flue-cured and the dark-fired type. The estimate of such counties is for the flue-cured type only.

TABLE XVII.—*Estimated annual production of the flue-cured type of tobacco in the Old Belt section of Virginia, North Carolina, and Tennessee, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.	Counties.	Pounds.
Virginia:		North Carolina:		North Carolina—Con.	
Pittsylvania	16,000,000	Granville	7,500,000	Guilford	2,000,000
Halifax	14,000,000	Rockingham	7,000,000	Yadkin	1,000,000
Mecklenburg	7,500,000	Caswell	6,000,000	Wilkes	500,000
Henry	4,000,000	Person	5,500,000	Iredell	500,000
Lunenburg	4,000,000	Stokes	5,000,000	Tennessee:	
Franklin	3,500,000	Vance	5,000,000	Greene	500,000
Charlotte	2,000,000	Franklin	5,000,000	Scattered	500,000
Patrick	2,000,000	Alamance	4,000,000		
Brunswick	1,000,000	Wake	3,000,000	Total, North Carolina and Tennessee	65,000,000
Nottoway	500,000	Surrey	3,000,000		
Prince Edward	500,000	Durham	2,500,000		
		Warren	2,500,000		
Total for Virginia	55,000,000	Orange	2,000,000		
		Davidson	2,000,000		

Grand total, Old Belt section, 120,000,000 pounds.

This Old Belt section might be still further subdivided into the eastern and western subsection, or into the Winston Salem and the Danville subsections. The soil grows progressively more clayey as one proceeds westward, and the change is reflected in the quality of the tobacco produced. The western subsection is noted for the large proportion of leaf adapted for use as fillers for flat plug as manufactured so extensively at Winston Salem, N. C. Henry County, Va., and Stokes County, N. C., are particularly noted for the fine quality of fillers produced suitable for this class of plug.

The proportion of mahogany or red tobacco in this western subsection of the Old Belt is also much greater than in the eastern part. An approximate line separating the western from the eastern parts of the Old Belt would show Franklin and Henry Counties in Virginia and a part of Rockingham County in North Carolina and all west to the Blue Ridge in the western or Winston Salem subsection of the Old Belt section.

Danville, Va., Winston Salem, N. C., and South Boston, Va., are the most important first-hand markets for the Old Belt. These three markets sell from first hands fully 50 per cent of the total Old Belt productions.

THE NEW BELT SECTION.

Table XVIII gives a list of the important producing counties of the New Belt section, with estimates of average production.

TABLE XVIII.—*Estimated acreage of annual production of flue-cured tobacco in the New Belt sections of North Carolina and South Carolina, distributed by counties, and the total production in all districts of Virginia, North Carolina, South Carolina, and Tennessee.*

Counties.	Pounds.	Counties.	Pounds.	Counties.	Pounds.
North Carolina:		North Carolina—Con.		South Carolina:	
Pitt	12,000,000	Jones	2,000,000	Marion	5,000,000
Nash	8,000,000	Columbus	2,000,000	Darlington	5,000,000
Wilson	6,000,000	Bertie	1,750,000	Florence	3,500,000
Greene	6,000,000	Craven	1,500,000	Williamsburg	3,000,000
Lenoir	5,000,000	Sampson	1,000,000	Clarendon	2,500,000
Johnston	3,500,000	Cumberland	500,000	Dillon	2,000,000
Duplin	3,500,000	Beaufort	500,000	Horry	2,000,000
Robeson	3,500,000	Bladen	500,000	Lee	500,000
Wayne	3,000,000	Harnett	250,000	Sumter	500,000
Martin	3,000,000	Other counties	1,000,000	Georgetown	500,000
Halifax	2,500,000			Other counties	500,000
Wake	2,000,000	Total for New Belt of eastern North Carolina	70,000,000	Total for New Belt of South Carolina	25,000,000
Edgecombe	2,000,000				

	Pounds.
Total New Belt of eastern North Carolina and South Carolina	95,000,000
Total Old Belt	120,000,000
Grand total annual production of flue-cured tobacco for all districts of Virginia, North Carolina, South Carolina, and Tennessee	215,000,000

As in the case of the Old Belt section, the New Belt section might with some reason be again subdivided into two subsections representative of noticeable differences in the quality of the tobacco itself, broadly speaking, and of methods of cultivation and handling, particularly in respect to the manner of placing the tobacco on the market. As a whole the South Carolina soils are more sandy than those of the eastern North Carolina section, particularly the portion east of the Pedee River, resulting in some modifications of body and color in the tobacco produced.

The South Carolina product is on the whole perhaps paler in color and lighter in body, though this distinction of course would not hold for certain sections of South Carolina, particularly that portion west of the Pedee. The eastern part of Darlington County, in the vicinity of Montclare, and Clarendon County, in the Pudding Swamp neighborhood, are especially famed for the fine quality of leaf produced.

In the South Carolina section the growers have adopted the practice in the last few years of selling the tobacco ungraded and not tied into hands, although of course the very fact of priming the tobacco on the plant a few leaves at a time as they ripen makes for a certain degree of grading, since the ground leaves, middle leaves, and tops naturally fall more or less into curings by themselves. In 1909 it was estimated that fully 80 per cent of the South Carolina crop was sold in this way, ungraded, and not tied up. This practice serves still further to differentiate the South Carolina portion of the New Belt from the eastern North Carolina portion.

In noting the production by counties as shown in Table XVIII for eastern North Carolina it will be seen that the growing of tobacco almost ceases in Cumberland, Sampson, and Bladen Counties. This section of country is really the dividing line between the eastern North Carolina section as a separate district and the South Carolina section. The border counties, Robeson and Columbus, of North Carolina, are really more closely identified with the South Carolina district than with the eastern North Carolina portion of the New Belt.

The principal market centers of the New Belt are Wilson, Greenville, Kinston, and Rocky Mount in eastern North Carolina, and Mullins, Darlington, Lake City, and Timmonsville in South Carolina. These eight markets sell from first hands about 70 per cent of the total New Belt crop. The remainder is divided between a considerable number of small markets selling usually from 1,000,000 to 3,000,000 pounds each.

All things considered, this flue-cured type of tobacco is unsurpassed in universal popularity and general adaptability to a variety of uses, including granulated and cut smoking tobacco, both paper and all-tobacco cigarettes, and plug filler and wrapper; in fact it is adapted to practically all the regular forms in which tobacco is used except standard cigars and snuff. In color and general appearance it is very attractive, while its low nicotine content, mildness, aromatic sweetness, fragrance, and good keeping qualities render it very satisfying to the user.

The two subdivisions of the flue-cured district are outlined on the map (Pl. I, in pocket).

WHITE BURLEY TOBACCO.

ORIGIN AND EARLY DEVELOPMENT.

The cultivation of tobacco in Kentucky and Ohio was introduced by the pioneer settlers from Virginia and Maryland in the period succeeding the Revolutionary War. Many of these settlers occupied the lands along either side of the Ohio River.

Whether the development of Burley tobacco in this section was from the Maryland type of seed, like that of the eastern Ohio export tobacco, or from the Virginia type of seed, history does not make clear. Burley tobacco more closely resembles the tobacco of Maryland in general appearance than it resembles the Virginia type. This is true in point of general character, including body and color, and both are air-cured tobaccos, while the Virginia types, excepting the "sun-cured," are cured by artificial heat, either by open fires or by flues.

The origin of the name Burley is uncertain, but is said by some to be derived from the name of a grower or, perhaps, as others think, it was so named for Lord Burleigh of England; in any event, a Burley tobacco was cultivated in this Ohio River section for some years prior to the Civil War. It was not, however, the White Burley as we now know it.

The development of the present type of White Burley, possessing the peculiar creamy-white color modification of stem, stalk, and veins, and also to a degree of the web of the leaf itself, took place, according to the present belief, as a mutation or sport. It seems pretty well established that White Burley originated on the farm of Mr. George Webb near the village of Higginsport, Brown Co., Ohio.

The following account of the origin of the new white tobacco, as it was called, written in 1875 by Mr. A. F. Ellis, who was a neighbor of Mr. Webb at the time, is quoted from the Western Tobacco Journal:

> White Burley tobacco first made its appearance in the year 1864, near the village of Higginsport, Brown County, Ohio. In the spring of that year one George Webb procured from G. W. Barkley, of Bracken County, Ky., a small portion of tobacco seed of the kind then known as Little Burley. He sowed a part of this seed and grew a bed of fine-looking plants, but when ready to transplant found among them a few of a peculiar white or yellow color and, supposing them to be diseased or dwarfed plants, pulled them up and threw them away.
>
> The next year, being scarce of seed, he sowed the remainder of this old seed and again found a portion of the same kind of plants that he had thrown away the year previous. This excited the curiosity of Mr. Webb and others, whose attention had been called to these strange-looking plants, and they were induced to transplant them, raising in all about 1,000 plants, which proved to be healthy and thrifty, and when fully ripe were almost of a cream color, making a great contrast with other tobacco.
>
> The result of this experience created quite a sensation throughout the neighborhood and many growers came from every direction to see what they called a freak of nature. The tobacco cured a bright yellow or cream color, but was adjudged bitter to the taste. Some concluded that although the tobacco colored well and produced the pounds, on account of its bitter taste it would not be safe to plant any large portion of the next crop of this kind of tobacco, although considerable seed had been saved.
>
> The plant beds that were sown of this seed in the year 1866 were found to contain a much larger portion of white plants than green ones, and a sufficient quantity were transplanted to produce 20,000 pounds of cured tobacco. Two hogsheads of this production were shipped to the Cincinnati market and sold at a high price. The purchaser shipped the same to the St. Louis Fair of 1867 and, after being awarded the first and second premuims for cutting leaf, sold it for $58 per hundred.
>
> The remainder of this kind of tobacco was purchased by the firm of which I was a member, and entered at the Cincinnati Annual Tobacco Fair of the same year to compete for the best 10 hogsheads of any class, and awarded the third premium, and was afterwards sold for $34 per hundred.
>
> The record thus made at the several tobacco fairs of 1867 induced many of the enterprising planters of Brown County, Ohio, and Bracken County, Ky., to plant largely of this kind of tobacco, and its culture has been gradually increasing throughout the entire district used for producing cutting tobacco until the present time, when it would be difficult to find any person in this large tobacco region so ignorant of his pecuniary interest as to plant any other kind.

> The character of the soil that first produced the White Burley is strong, black, coarse river-hill land, and underlaid with limestone. The growth of timber cut from this land was principally sugar, lin, buckeye, ash, walnut, hickory, oak, and beech. Although it is well known to the country dealer that much the best quality of White Burley is grown on this kind of land, experience has satisfied us that any good, strong, old or new land that will produce any other class of cutting tobacco will produce this.
>
> In 1867 I gave this growth of tobacco the name of White Burley, owing to its similitude in size and texture to the ordinary Burley, and to its almost white color when thoroughly ripe. The cultivation is the same as for any other cutting tobacco.

As this almost contemporaneous account indicates, the new white tobacco came first into prominence as a superior type for the manufacture of fine-cut chewing tobacco.

The Virginia type of plug, manufactured from the sweet air or coal cured tobacco of Virginia and North Carolina, had dominated the trade in chewing tobacco up to the breaking out of the Civil War. The war, however, completely demoralized this Virginia trade. In its place fine-cut chewing tobacco made from the Yellow Pryor type of leaf produced in the Mason County, Green River, and Missouri districts of the West and manufactured extensively in Cincinnati, Louisville, and St. Louis became very popular, as did also plug made from the Green River type of leaf. It was milder than the Virginia product and after the war the trade, except locally, did not go back to the Virginia fillers. But these new western products, fine cut and plug made from the western Yellow Pryor leaf, in turn had to give way to the new White Burley tobacco.

The unusual suitability of the White Burley for plug was not generally recognized, however, until the later seventies of the last century. The regular filler stock of the Green River type was very scarce and high in 1875 and some of the St. Louis and Jersey City factories tried in a small way some of the heavier red grades of Burley not suited for cutting stock, which were low in price from lack of demand. Consumers liked the new product and it proved especially pleasing to manufacturers because of the large quantity of cheap flavoring liquids which it would readily absorb. Some of these brands are reported to contain as much as 40 per cent of flavoring sauces.

The rapidity of this early development in the popularity and production of Burley may be illustrated by comparing the production of tobacco in Brown, Adams, and Clermont Counties in Ohio in 1870 and 1880. These three counties comprise the important Burley-producing section of Ohio. In 1869 they produced, according to the Census returns, 4,009,978 pounds of tobacco and in 1879 this was increased to 10,823,183 pounds, or more than 250 per cent. The normal production of Burley in these three counties, from 1905 to 1909, was about 13,000,000 pounds annually.

The White Burley strain of seed was also introduced into and rapidly extended in the neighboring counties across the river in Kentucky, and, owing to a much greater area of suitable land, the production of White Burley in Kentucky soon far exceeded in amount that produced in the Ohio portion of the Burley district.

To-day, practically all of the Burley seed used is of this improved type. The name Red Burley is frequently used to-day, but refers more particularly to differences in the cured leaf from the same seed. Some leaves are redder, or more colory, than others, depending upon the soil, season, or other local conditions, often as they occur in the same field. This leads us to the consideration of the soil as a factor of importance, as it influences the color and other desirable features of Burley tobacco.

SPECIAL SOIL INFLUENCES ON PRODUCTION.

White Burley tobacco originated and has had its principal development on the phosphatic limestone soils of central and northern Kentucky and southern Ohio. They are as a whole among the richest in mineral plant food materials and among the most fertile soils to be found anywhere.

It is well known that the soil itself exerts a most important influence on the character of tobacco, but it is difficult, if not impossible, to single out any one soil factor as the all-important or controlling one which can be observed in actual field results. It is known that phosphates in considerable available supply tend to lighten the color of vegetation, but this is not sufficient to account fully for the peculiar chlorosis of Burley, because some of the brightest Burley tobacco produced is grown on soils where the supply of phosphorus is only normal. The same may be said concerning lime also. In fact the finest and brightest Burley best suited to high-grade cutting purposes is most likely to be produced on freestone soils rather than on limestone soils. For plug fillers, however, which form the largest single item in the consumption of Burley tobacco, the heavier-bodied types produced on the rich limestone soils, though somewhat darker in color, are generally preferred.

It is true, therefore, that the soil exerts a dominating influence in producing a Burley tobacco of good quality, but this seems to be due to a combination of factors rather than to any particular ones that can be specified with precision. It is of course quite likely that the special soil conditions had something to do with the original mutation of the White Burley characteristics. Any other type of seed planted on typical Burley soil will produce a brighter, more porous tobacco than if planted, for example, on a typical heavy, dark, export-tobacco soil, but it will be far from equaling the product obtained from Burley seed in this respect. Conversely, the hereditary influence of Burley seed is also most remarkable. Even when planted on a most unpromising soil from the standpoint of Burley, the characteristic cream-colored stalks and midribs are always noticeable. On these poorly adapted soils, of course, the cured product will not possess the same degree of excellence as on the typical Burley soils. A portion of a field of thrifty young Burley plants in the bluegrass section (Fayette County, Ky.), is shown in figure 29. The peculiar characteristic white venation shows even in the picture. On the less hilly portions of the Burley district 2-horse machine setters are much used in transplanting the young plants from the seed bed to the field. Such a machine is shown at work in figure 30. The use of these machines is also common in nearly all the cigar-tobacco districts. While the prepotent strength of this inherited modified chlorophyll characteristic of White Burley is, however, very remarkable, yet it is only on certain soils that all the points of excellence will be present sufficiently to make its production commercially successful under normal conditions.

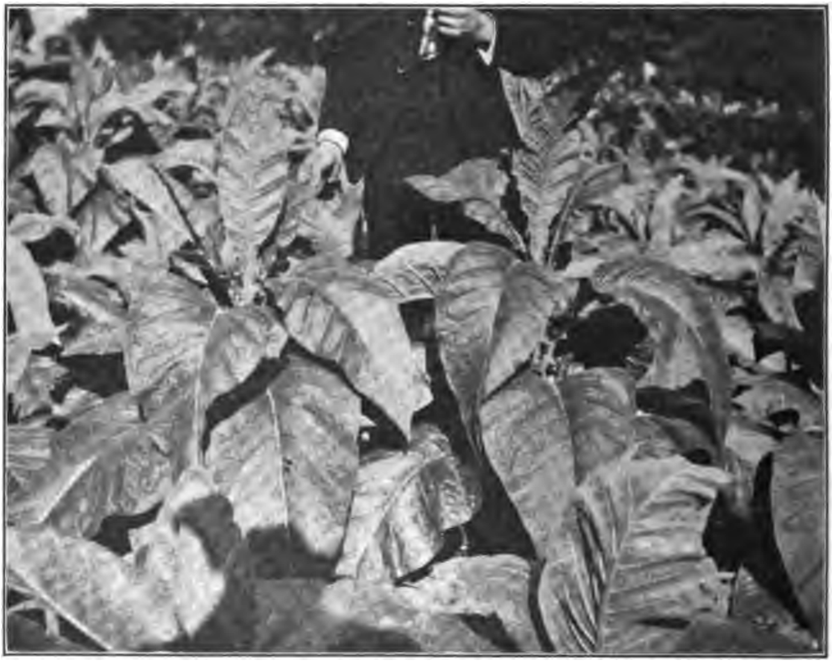

FIG. 29.—Part of a field of thrifty young Burley tobacco plants in the bluegrass section, Fayette County, Ky.

Friable mellow soils of a clayey or of a silty nature, strong and durable in natural fertility, and which have laid long in grass are at least among the most desirable requisites for producing a good grade of Burley whether or not they are exceptionally rich in lime or phosphates. Since 1907, because of the unusual scarcity and consequent high prices of Burley, due to the efforts of the Burley Tobacco Growers' Association to restrict the supply and advance the price, unusual efforts have been made to introduce the production of Burley tobacco in a large number of new sections. These undertakings, on account of the scarcity and high prices, have usually proved profitable to the grower, but the discrimination in prices as compared with better grades of Burley was in many cases very marked. With normal market conditions this low-grade Burley produced on unsuitable soils in all probability would have been still further discriminated against to the extent of rendering its production unprofitable.

It is noteworthy, however, that many of these experimental crops of Burley in untried sections proved much better in quality than expected and compared very favorably with the product of the established Burley territory, and it seems quite possible that some of these new locations where Burley has been introduced may develop into permanent producing territory.

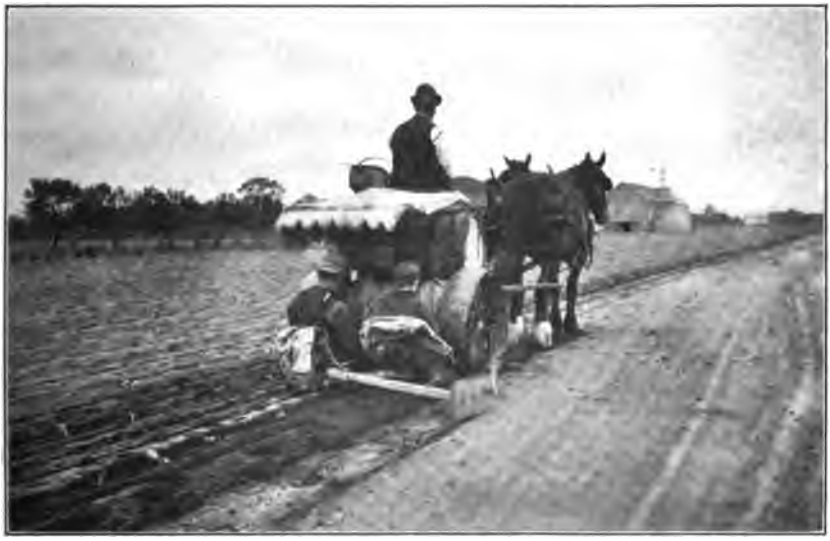

FIG. 30.—Transplanting and watering tobacco seedlings by machine, a common method in parts of the Burley district and in nearly all the cigar-tobacco districts.

In 1909 scattered crops of Burley were tried here and there over much of piedmont and middle Virginia and in some parts of the valley between the Blue Ridge and the Alleghenies. So far as could be judged from the results of these experiments, considerable good Burley was grown on the strong, red, nonlimestone soils in the piedmont and on some of the limestone soils of the valley. Most of the Burley produced on the gray soils of the middle and eastern section of the State, however, was of very inferior quality.

For the purposes of this bulletin it will be unnecessary to dwell longer on the soil requirement of White Burley or on the results of attempts to produce a satisfactory product in new sections. Figure 31 shows a view of a typical curing barn of the better type common in the Burley district of Kentucky and elsewhere.

GENERAL CHARACTERISTICS AND USEFULNESS.

DOMESTIC USE.

Burley tobacco, like the flue-cured, is a modern type developed since the Civil War. It has also many of the same points of excellence, making it well adapted to domestic manufacture and consumption. It is even milder than flue-cured, and since it is an air-cured type it is entirely free from the odor or flavor of smoke. It runs to light colors and burns well, making it quite well adapted for use in smoking mixtures. The size of leaf is desirable and when grown on proper soils is very smooth and fine of fiber.

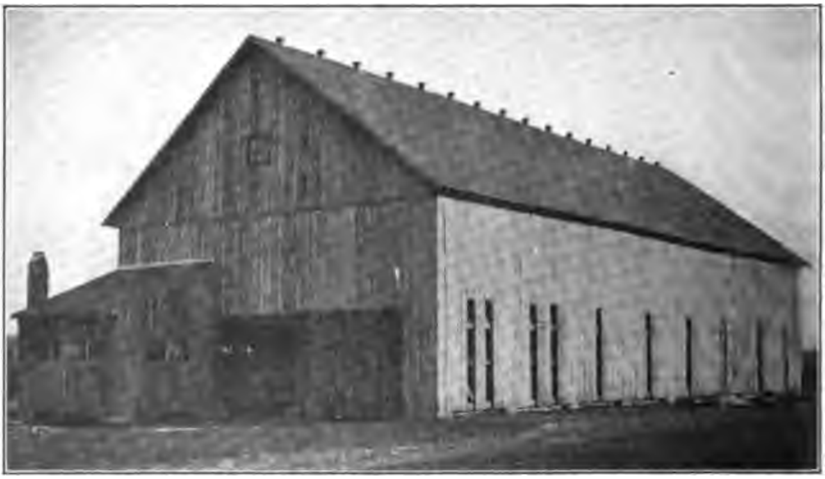

FIG. 31.—Common type of curing barn in the Burley district of Kentucky.

In one important respect Burley tobacco is in a class by itself and superior to any other type, that is, in its remarkable capacity for absorbing liquid sweetening and flavoring materials. From the standpoint of the manufacturer this capacity renders it a most economical tobacco to use, as these sauces are much cheaper per pound than tobacco itself, and from the standpoint of the consumer who likes his tobacco highly flavored and sweetened, it is also a most desirable quality. This unusual absorptive or "drinking" capacity, as it is often called, is really the foundation of the great success of Burley tobacco.

In point of real tobacco quality, as pungency, aroma, or fragrance, Burley is rather negative and weak, but as used this weakness is really another point in its favor. This lack of decided character of its own, combined with its great absorptive capacity, makes it an easy matter to flavor it up artificially in almost any way desired. Immense quantities of this heavily sweetened western plug of the so-called navy type is manufactured in the great factories at St. Louis, Louisville, and elsewhere. Burley is also the principal type used in the manufacture of the great array of cut-plug smoking tobaccos and of fine-cut chewing tobacco. It is also useful for granulating purposes, and some of the best grades make the finest cigarette and twist wrappers. In recent years the expansion in the use of chewing tobacco has come nearly to a standstill. Very few young men become chewers. They smoke instead. Among pipe tobaccos those of the cut-plug type, made principally from Burley, are increasing very rapidly in popularity and use.

FOREIGN DEMAND.

The development in use of Burley tobacco for domestic consumption since the Civil War has been astonishing and has far outstripped its closest rival, the flue-cured type, in this respect among the manufacturing types of tobacco. Nevertheless, it has not attained any importance as an export type, and in this regard has been far outstripped by the flue-cured type.

This lack of progress as an export type is quite clearly due to two or three easily discernible factors. Foreigners as a whole chew tobacco but little, and furthermore the laws of our most important foreign customer, Great Britain, do not permit of the use of any form of sweetening or flavoring in manufactured tobacco products. This, of course, largely negatives the specific usefulness that Burley might have to make it particularly valuable there. Finally, the price of Burley, due to a strong, more or less constant domestic demand, has been in recent years unfavorable to its purchase by foreign countries. In the early nineties of the last century, however, when prices were very low, Burley was exported quite extensively, particularly to Germany, Belgium, and France. Exports of this type would doubtless again increase should prices drop to a low figure for any considerable length of time. The foreign demand for Burley is mostly for the low grades usually designated as common red smokers. Under conditions as they are, however, the quantity of Burley tobacco annually exported is small and probably does not exceed 5 per cent of the crop.

GRADES AND PRICES.

Burley tobacco possesses very little gum or oil, is comparatively low in nicotine, is of light color and body, and is rather dry and lusterless in appearance.

The small proportion of the fine grades suitable for wrappers for cigarettes and twist are of very fine fiber, of clear, uniform, solid color, very soft and smooth in texture, and, of course, free from holes, raggedness, or other mutilation. The supply of these grades in a crop is always small, and they can only be picked up here and there in small lots. The demand, of course, is comparatively small also, but these grades usually bring 20 cents or more a pound. Freshly cleared hillside land of a loose, porous nature is most likely to produce these finer grades. Mason County, Ky., has long had the reputation of producing a considerable portion of this high-grade wrapper leaf. Among the newer sections the hill lands of the West Virginia Burley district produce a fine grade of leaf, much of which is useful for wrapper purposes. The grades adapted for cutting purposes require good, bright, clean stock of reasonably fine texture. The use of these grades for manufacturing the great number of popular brands of plug-cut smoking tobacco and also for fine-cut chewing tobacco, which requires some very fine, bright leaf, makes the demand for them quite large. The cut-plug stock is usually obtained from the grades known as bright lugs and trash from near the bottom of the plant.

The greatest quantity of Burley is, of course, used for plug filler of the heavily sweetened type. For this purpose the most important requisite is porosity, in order that it may absorb and retain the large amount of sauces used in its manufacture. Color is not of so much importance, as it is lost in manufacture, but the leaf should be sound and of good body and substance. This type of leaf is produced in large quantities on the rich, level, bluegrass fields of central Kentucky.

When Burley was first extended to these rich bluegrass fields it was thought the leaf would be too coarse and dark. The expedient of closer planting and higher topping, however, corrected much of this tendency, and it is the general custom to set 7,000 to 8,000 plants to the acre on the best bluegrass soils and about 5,000 or 6,000 to the acre on the hill lands.

The lower ground leaves or flyings of flimsy texture are used largely for granulating purposes in smoking mixtures and for export.

The average selling price of Burley tobacco from first hands has been subject to extreme fluctuations. In 1893 and 1894 prices were very low, averaging about 4 to 5 cents a pound. The general average through a long period of years, however, has probably been from 8 to 9 cents a pound, although of course individual crops might sell very much above or below the average for the time, according to the quality of the crop as placed on the market.

Burley tobacco is subdivided into a great array of grades or classes, varying according to the influence of soil, season, and the skill of the individual grower. But only about six fundamental grades are generally recognized, as they naturally occur in any crop or, in fact, upon a single plant. Each plant will usually give from two to four leaves of each of the following grades, beginning at the top of the plant: Green or red tips, red leaf, bright leaf, lugs, and trash. At the very bottom there are generally one or two small trashy leaves called flyings. On some plants or in some crops naturally the so-called bright leaf may be darker than the so-called red leaf from another plant or crop, and vice versa, but the character of the leaf for a given plant usually varies in grade according to the rule stated. In addition to these grades defective grades are usually sorted out and classed as worm eaten, house burned, etc.

After the tobacco is placed on the market this plan of grading is lost sight of very largely, although the names of the grades themselves are retained and leaf, trash, or lugs, etc., will be dark red, bright red, or colory, according to a standard existing in the minds of the members of the tobacco trade.

The prices set by the Burley growers of Kentucky in 1904 in their efforts to obtain better returns from their crops are of interest in throwing light on the comparative value of the different grades into which Burley is naturally assorted by the farmer.

The schedule of prices proposed was for loose tobacco assorted and tied into hands, delivered in soft winter order. When redried and delivered in keeping order the prices were to be 15 per cent higher. The schedule is shown in Table XIX.

TABLE XIX.—*Schedule of prices proposed by the growers' organization for loose Burley tobacco in 1904.*

Classes.	Price per 100 pounds.		
	Grade 1.	Grade 2.	Grade 3.
Flyings	$10	$7	$5
Trash	12	10	7
Lugs [1]	16	12	9
Red leaf	13	11	9
Bright leaf	18	14	12
Tips [2]	10	8	7

[1] Cigarette lugs and fancy leaf from $20 to $26.

[2] Green, damaged, frosted, and common black tips from $3 to $6.

A number of factors must of course be considered to determine the grade of the same class of leaf as fineness, brightness, size of leaf, body, etc., and at best they serve only as approximations. Figure 32 shows samples of several grades of Burley leaf, varying in quality from poor to fine.

The most important markets for the sale of Burley tobacco are Cincinnati, Ohio, and Louisville and Lexington, Ky. A considerable proportion of the tobacco that goes to the Louisville and Cincinnati markets, however, is not first-hand farmers' tobacco, but is leaf that had been bought up by speculators and dealers in the country and then shipped to these markets for sale.

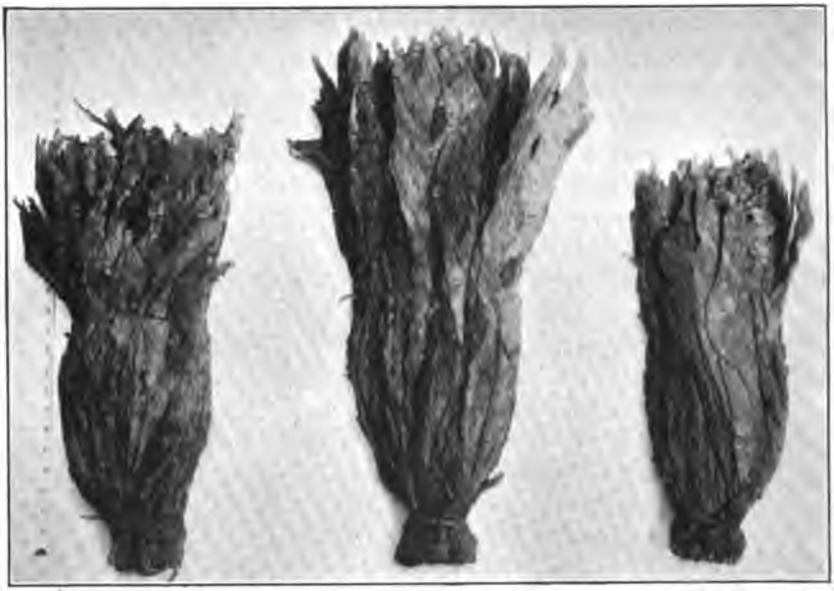

FIG. 32.—Burley tobacco, flyer, colory leaf, and red-plug filler. (Photographed by the Bureau of Soils.)

FLUCTUATIONS IN PRODUCTION.

From 1907 to the fall of 1910 the price of Burley has been very high because of the artificial condition created by the growers' selling organizations in their efforts to restrict the supply and elevate the prices. In consequence the price average has been more than 12 cents a pound during most of this period.

With tobacco, as with almost every other agricultural product in which the available acreage is not naturally restricted, there is an approximate price at which the acreage and production will naturally tend to expand rapidly and another at which it will tend to decrease. So many factors are at work that it is, of course, impossible to assign any exact limits of price at which either of these phenomena would become operative, but it is usually possible to do so approximately under given conditions. Certainly at a price near or below cost the production should automatically begin to diminish and at a price high enough to return a greater profit than other available products the acreage and production should automatically tend to increase.

In the case of Burley tobacco there is nothing to indicate any scarcity of soil adapted to its cultivation. Under existing natural conditions the writer believes that the production of Burley should tend automatically to expand at a general price level of about 10 cents a pound, and it would probably tend to decrease should it get down to 8 cents or below for any considerable length of time.

DISTRIBUTION IN USE.

As it passes finally into consumption the distribution in use of Burley tobacco on a farm-weight basis is estimated to be about as shown in Table XX.

TABLE XX.—*Estimated approximate distribution in use of Burley tobacco.*

Grade.	Pounds.	Grade.	Pounds.
Plug filler	100,000,000	Granulating	3,000,000
Cut-plug stock	60,000,000	Cigarettes	3,000,000
Long-cut smoking	15,000,000	Export	9,000,000
Twist	10,000,000		
Fine-cut chewing	10,000,000	Total	215,000,000
Scrap chewing tobacco	5,000,000		

The great bulk of the plug-filler stock mentioned in Table XX is used in the manufacture of plug tobacco of the heavily sweetened type. Considerable of the best Burley is used in the manufacture of some of the western so-called natural-leaf types of flat plug.

DISTRIBUTION OF ACREAGE.

The great bulk of Burley tobacco is grown in Kentucky, in the central and northern portions of the State. Table XXI shows the estimated distribution of its growth in Kentucky, Ohio, and Indiana.

The tobacco grown in West Virginia is practically all Burley. Reliable estimates of the quantity produced are very difficult to obtain. Estimates by men in touch with the situation range from 5,000 000 to 15 000 000 pounds, produced mostly in Cabell, Putnam, Lincoln, and Kanawha Counties, south of the Kanawha River.

Local buyers are stationed at various points in the producing territory. The principal shipping points are Hurricane, St. Albans, and Milton. For the sale of the 1910 crop a loose-leaf auction warehouse market was established at Huntington, W. Va. West Virginia Burley for the most part had previously found its way finally to the Cincinnati or to the Richmond market. In quality West Virginia Burley is fine and smooth and produces some fine twist and cigarette wrappers and good cutting leaf. The yield, however, is rather small, the lay of the land being hilly and the soil rather thin and not highly improved as a rule.

TABLE XXI.—*Estimated annual production of Burley tobacco in Kentucky, Ohio, and Indiana, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.	Counties.	Pounds.
Kentucky:		Kentucky:		Ohio:	
Adair	500,000	Jessamine	2.000,000	Brown	6,000,000
Anderson	3,000,000	Kenton	1,500,000	Adams	5,000,000
Barren	2,000,000	Larue	500,000	Clermont	2.000,000
Bath	4,500.000	Lewis	2,500.000	Gallia	1,000,000
Boone	3,500,000	Lincoln	500,000	Noble	1,000.000
Bourbon	7,000,000	Madison	2,000,000	Scioto	500,000
Boyd	500.000	Magoffin	500,000	Monroe	500,000
Boyle	2,000.000	Marion	1.000,000	Lawrence	250,000
Bracken	6,000,000	Mason	8.000,000	Hamilton	250,000
Breathitt	250,000	Meade	500,000	Highland	250.000
Breckenridge	1.000,000	Mercer	1,500,000	Washington	250,000
Bullitt	2,000,000	Metcalfe	1,000,000	Other counties	1,000,000
Campbell	1.000,000	Montgomery	4,000,000		
Carroll	4.000.000	Nelson	2,500,000		
Carter	1,500,000	Nicholas	4,500,000	Total Burley in Ohio	18,000,000
Casey	1.000,000	Oldham	500,000		
Clark	5,500,000	Owen	9,000,000	Indiana:	
Elliott	250,000	Pendleton	4,500,000	Switzerland	3,000.000
Fayette	8,000,000	Robertson	2,500,000	Jefferson	1,500,000
Fleming	4,500.000	Rowan	500,000	Dearborn	1,500,000
Franklin	3,000,000	Scott	8,000,000	Ohio	1,000,000
Gallatin	2,500.000	Shelby	6,500,000	Clark	500,000
Garrard	2.000,000	Spencer	2,500,000	Other counties	500,000
Grant	5,500,000	Trimble	3,500,000		
Green	1,000,000	Washington	4,500,000		
Greenup	2,000,000	Woodford	5,000,000	Total Burley in Indiana	8,000,000
Hardin	1.000.000	Other counties	1,000,000		
Harrison	6,000,000				
Hart	2,000,000				
Henry	6,000,000	Total Burley in Kentucky	170,000,000		
Jefferson	500.000				

Missouri, principally in Platte and Clay Counties, has recently been coming to the front as a producer of a very good grade of Burley. The annual production is uncertain, but it is estimated at upward of 3,000,000 pounds for the three years preceding 1910 and is probably 8,000,000 to 10,000,000 pounds for 1910. Up to about 1880 Missouri had produced almost entirely dark tobacco of the Yellow Pryor type. Some was fire cured or coal cured, but the larger part was air cured. The longer, coarse tobacco, constituting the bulk of the Missouri crop in the old days, went principally to England and Ireland. The finer, lighter bodied tobacco produced on the hills and Missouri River bluffs was used largely in domestic manufacturing. The principal production was in the counties along the Missouri River, mostly on the north side. Chariton, Randolph, Howard, and Boone Counties were the heaviest producers. In 1876 Chariton County alone produced 14,000,000 pounds of tobacco.

During the eighties much of the acreage shifted to Burley or owing to low prices and greater interest in other crops dropped out altogether, until the production of all the dark tobacco and nearly all the Burley had ceased altogether in the early years of the present century. About 1897, however, a Kentuckian named Turner, residing in Platte County, Mo., chanced to think that Burley would grow successfully in that section. A trial crop was raised near Weston with reasonable success and a number of other farmers, assisted principally by renters from Kentucky, began to plant small crops. The soil in that section is of limestone origin, is very rich and productive, and the land is somewhat rolling and impresses one as favorable for Burley tobacco. Up to 1907 the crop near Weston amounted to about a half million pounds of tobacco yearly. With the cutting out of the 1908 crop of Burley in Kentucky, however, there was a considerable immigration of renters to the Weston neighborhood. The production expanded very rapidly and the 1910 crop of Burley near Weston and at local centers in adjoining counties amounted probably to 3,000,000 or 4,000,000 pounds. The older Missouri tobacco district, particularly in Chariton and Carroll Counties, has also greatly increased its production of Burley since 1907, probably to over 3,000,000 pounds in 1910, which, together with a scattered acreage in other parts of the State, means probably from 8,000,000 to 10,000,000 pounds of Burley tobacco produced in Missouri in 1910. The general character of the country about Weston, however, would seem to indicate that that section has the best chance to maintain its position as a tobacco country through periods of low as well as high prices.

A scattered acreage of Burley, quite large in the aggregate, is grown in a number of States, the most important being where the production has spread over into the adjoining One-Sucker and Green River districts of Kentucky and in Indiana. The scattered production is also considerable in the Greenville and upper Cumberland sections of Tennessee and in the Piedmont and valley section of Virginia. This scattered production is hard to estimate with any degree of accuracy, but if it were all tabulated it is believed that it would amount to at least 6,000,000 pounds.

Table XXII shows an estimate of the total average production of Burley for the country by States.

TABLE XXII.—*Estimated total average annual production of Burley tobacco in the United States, distributed by States.*

States.	Pounds.	States.	Pounds.
Kentucky	170,000,000	Scattered, principally in Tennessee and Virginia	6,000,000
Ohio	18,000,000		
Indiana	8,000,000		
West Virginia	8,000,000		
Missouri	5,000,000	Total Burley crop of the United States	215,000,000

This estimate of the production of Burley tobacco will manifestly not tally very closely with the actual or estimated production of Burley in any one of the last few years. As is well known, conditions themselves have been far from normal in the Burley territory. In 1908, under the influence of the Burley Tobacco Growers' Association, the planting of tobacco in much of the best Burley territory in Kentucky was entirely omitted. The Department of Agriculture estimated the total production of Burley in that year at 35,000,000 pounds. That was the first year that the department made estimates of total production by types, but unofficial estimates from reliable trade sources had generally given the Burley crop for the few years preceding at from 175,000,000 to 200,000,000 pounds per annum. In 1909 the department estimated the Burley crop at 244,800,000 pounds and unofficial trade estimates generally put it from 250,000,000 to 300,000,000 pounds. In 1910 the planting of Burley was estimated by the Department at 15 per cent more than in 1909. These two unusually large crops were manifestly abnormal and the result of abnormal trade conditions consequent upon the elimination of the 1908 crop.

Mr. T. M. Carrington, of Richmond, Va., in his annual presidential address before The Tobacco Association of the United States, at the tenth annual convention, July 2, 1910, stated that the estimated normal consumption of Burley tobacco was around 200,000,000 pounds per annum, which is probably not far from correct. In this light it is evident that the production of Burley can not permanently remain at an average near 250,000,000 or 300,000,000 pounds per annum until consumption has materially increased.

The estimates submitted in this bulletin, therefore, are not intended to represent any single crop of recent years nor to reflect the abnormal production of 1909 and 1910, but the effort has been made to represent about a normal production. It must be said, however, that but for the abnormal conditions the production of Burley in such new sections as Missouri, Tennessee, and Virginia would have been much less even than estimated above, or perhaps in many cases there would have been no production.

A study of the map of Kentucky in connection with the yield of tobacco, as given in Table XXI, will show a tier of counties in the western portion of the Burley district where the production is comparatively small. This section, including the western part of Bullitt, Meade, Hardin, and Larue Counties, represents a transition in type of soil from the typical phosphatic limestone section of the Burley district on the east to the dark-tobacco section on the west. As such it is quite an interesting feature. Until recently this section produced very little tobacco of any kind, but since 1907 production has spread rapidly.

The territory included in the principal Burley districts is shown on the map (Pl. II, in pocket).

GREEN RIVER TOBACCO.

GENERAL CHARACTERISTICS.

Westward from the Burley district in Kentucky lies a transition territory which produces only small quantities of tobacco. Farther west is the Green River district, where the type of tobacco grown is air cured like Burley, but the general character of the seed used, methods of cultivation, etc., are almost the same as in the dark-fired district covering the remainder of western Kentucky. Figure

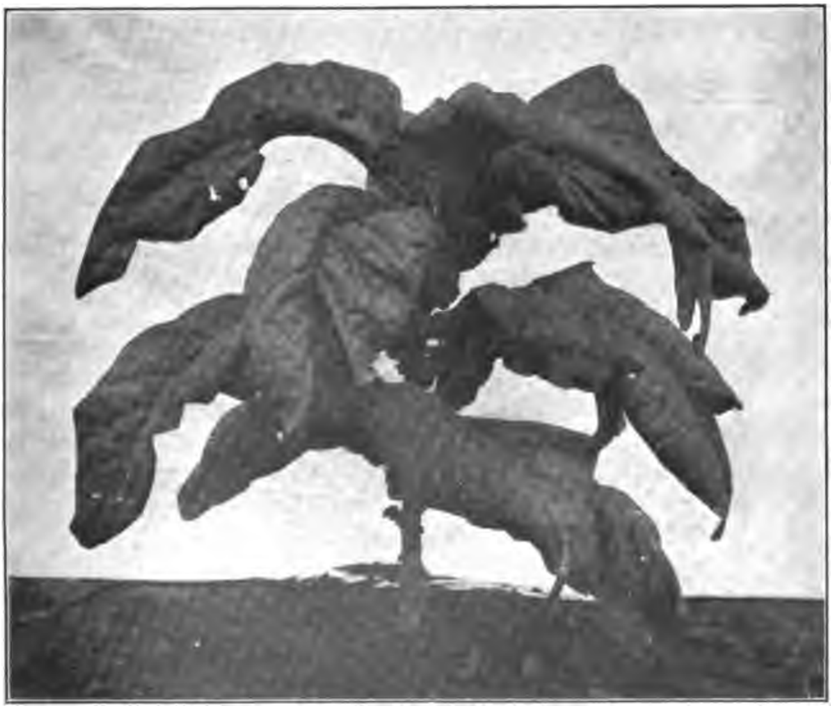

FIG. 33.—Typical Yellow Pryor tobacco plant, a favorite dark type commonly grown in the Green River district of Kentucky.

33 shows a typical plant of the Yellow Pryor type commonly grown in the Green River district.

PRODUCTION AND DISTRIBUTION IN USE.

The tobacco produced in the Green River district is not quite a typical manufacturing tobacco, nor yet is it an export type. It is classed as a dark tobacco and resembles in size of leaf and general appearance the product of the dark-fired district adjoining on the west, except that, being air cured, it is free from the odor and flavor of smoke and is more acceptable for domestic manufacture and consumption. Of the total production of Green River tobacco, which is about 35,000,000 pounds annually, it is estimated that about two-thirds is used in domestic consumption and one-third is exported, nearly all going to Great Britain. The portion consumed at home is used principally in the manufacture of long-cut smoking tobacco. Some of the finer grades are also used to some extent in the manufacture of fine-cut chewing tobacco.

GRADES AND PRICES.

Farmers generally make about three grades of the tobacco as they sort out the crop in preparation for market, classed as leaf, lugs, and trash. The average farm price of Green River tobacco is generally about 5 or 6 cents a pound. In 1903 and 1904 it averaged but little above 4 cents a pound. From 1907 to 1909, under the general influence of the efforts of the selling organization to enhance the price of nearly all of the export and manufacturing types of tobacco, it averaged from 7 to 8 cents.

The principal market point for the district is Owensboro, where are situated extensive leaf plants for handling the tobacco in preparation for the home trade or for export. Other important local receiving points for the district are Hawesville, Livermore, Hartford, Fordville, and Hardinsburg. A considerable portion of the Green River crop is also marketed through Louisville, principally at private sale, by sworn sample after inspection.

DISTRIBUTION OF ACREAGE.

The production of the Green River type of tobacco is confined almost entirely to five counties of Kentucky. An estimate of the total production is shown in Table XXIII.

TABLE XXIII.—*Estimate of the annual production of the Green River type of tobacco in Kentucky, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.
Daviess	15,000,000	Hancock	3,500,000
McLean	6,500,000	Grayson	750,000
Ohio	5,750,000		
Breckenridge	3,500,000	Total, Green River type	35,000,000

It will be noted that Daviess County produces nearly half of the entire quantity produced in the Green River district.

The map (Pl. II, in pocket) shows in outline the territory included in the Green River division of the dark air-cured districts.

ONE-SUCKER TYPES OF TOBACCO.

GENERAL CHARACTERISTICS AND USEFULNESS.

Like the tobacco of the Green River district, the One-Sucker type is classified as dark tobacco and like both the Burley and the Green River types it is cured without recourse to artificial heat, that is, it is an air-cured type. It is therefore adapted for use in domestic manufacture and consumption, but like the Green River type it is also to a considerable extent exported.

The type derives its name because the variety principally grown in the One-Sucker districts is known as One-Sucker tobacco from its habit of throwing out suckers somewhat less freely, perhaps, at the axils of the leaves after being topped than do most other kinds of tobacco. It is a narrow-leaved sort with very heavy midribs. The veins make a very acute angle with the midrib. On rich land it makes a very long, heavy leaf that is well suited for the "rehandling" export trade, principally to the west coast of Africa. Figure 34 shows a characteristic plant of the One-Sucker type.

SUBDIVISIONS OF THE ONE-SUCKER DISTRICTS.

SOUTHERN KENTUCKY AND UPPER CUMBERLAND SECTIONS.

The Green River district proper, as considered above, covers only about half of the north and south buffer area between the Burley district and the dark-fired district. The southern portion of this territory is occupied by what is known to the tobacco trade as the southern Kentucky and upper Cumberland section of the One-Sucker district.

The northern part of this One-Sucker section in Kentucky is sometimes designated as the "upper" Green River district in contradistinction from the (lower) Green River district proper.

The southern part of this district, along the headwaters of the Cumberland River in Tennessee and Kentucky, produces a brighter type of leaf than does the northern part of the district. Some of this upper Cumberland section produces a type of leaf hardly distinguishable at first glance from Burley. The country is very hilly and the tobacco is grown to a considerable extent on steep hillsides which, however, from the open, porous nature of the soil are not greatly subject to washing. Outcroppings of limestone are common and Burley is planted to a considerable extent here and there all through the upper Cumberland portion of the district.

Warren and Barren Counties in Kentucky are the largest producers of this southern Kentucky type. The principal receiving and shipping points in Kentucky are Bowling Green, Glasgow, and Scottsville. In Tennessee, Smith and Macon Counties lead in production and Hartsville and Carthage are the important shipping points. In Kentucky the best quality of One-Sucker tobacco, that is the finest, largest, and richest leaf, is produced in the western portion of Warren County, the eastern and southern part of Barren County, and the northern part of Allen County. The production is also much the most concentrated in this section and produces at least 50 per cent of the total One-Sucker crop in Kentucky.

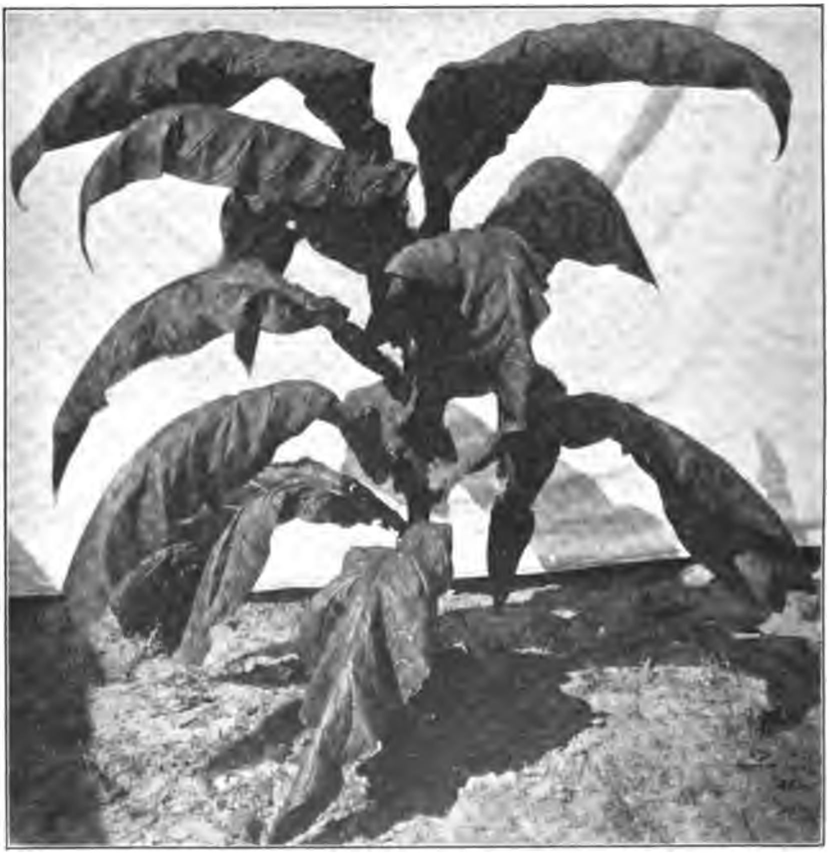

FIG. 34.—Plant of the One-Sucker type. The leaves are long and narrow and the veins make an unusually acute angle with the midrib.

In Tennessee, production is most concentrated in the northern part of Smith County, where much long tobacco particularly suited to the rehandling export trade is produced, and also in Macon County, where tobacco somewhat shorter but with good body and texture is produced, suitable for domestic manufacturing purposes.

THE ONE-SUCKER TYPE IN SOUTHERN INDIANA.

Across the Ohio River about opposite Daviess County in Kentucky there is a section in southern Indiana that also produces annually some 5,000,000 or 6,000,000 pounds of tobacco of the One-Sucker type. The leaf, however, is perhaps somewhat larger and coarser than it is in Kentucky and Tennessee. Formerly this district was much more extensive than at present and the tobacco produced was marketed principally at Evansville.

In the seventies and early eighties of the last century the maximum of production was reached in this southern Indiana section, after which it almost ceased in the early nineties. It was taken up again in a small way in the late nineties, however, and in the last few years, owing to high prices, has expanded probably to some 6,000,000 or 8,000,000 pounds in 1910. The heaviest producing center is the southwestern part of Spencer County. The soil is fertile and the tobacco produced is rather coarse but long and well suited to the rehandling export trade. The principal receiving and shipping points of the southern Indiana portion of the One-Sucker territory are Rockport, Booneville, and Dale.

PRODUCTION AND DISTRIBUTION OF ACREAGE.

The entire production of One-Sucker tobacco in the southern Kentucky, upper Cumberland, and southern Indiana districts is quite variable, tending to expand rapidly with good prices and to shrink when they are low. A fair average for recent years, however, is probably about 30,000,000 pounds per annum, of which about 18,000,000 pounds is produced in Kentucky, 7,000,000 pounds in Tennessee, and 5,000,000 pounds in southern Indiana. Under the somewhat artificial condition of very recent years the combined production of the One-Sucker types of tobacco in these districts has run probably nearer 35,000,000 pounds than 30,000,000.

The production in the One-Sucker districts of Kentucky, Tennessee, and Indiana is shown in Table XXIV.

TABLE XXIV.—*Estimated annual production of the One-Sucker type of tobacco in Kentucky, Tennessee, and Indiana, distributed by counties.*

Counties.	Pounds.
Kentucky:	
Warren	4,500,000
Barren	3,500,000
Allen	2,500,000
Simpson	1,500,000
Butler	1,500,000
Logan	1,000,000
Taylor	1,000,000
Monroe	1,000,000
Grayson	500,000
Metcalfe	500,000
Cumberland	250,000
Edmonson	250,000
Total in Kentucky	18,000,000
Tennessee:	
Smith	2,500,000
Trousdale	500,000
Sumner	750,000
Tennessee—Continued.	
Macon	1,500,000
Jackson	1,000,000
Clay	500,000
Other counties	250,000
Total in Tennessee	7,000,000
Indiana:	
Spencer	2,500,000
Warwick	1,500,000
Dubois	750,000
Perry	250,000
Total in Indiana	5,000,000
Grand total, One-Sucker type, in Kentucky, Tennessee, and Indiana	30,000,000

GRADES AND PRICES.

Growers in the One-Sucker districts assort the crop generally into about three grades, leaf, lugs, and trash, which they have been selling at an average of about 6 to 7 cents a pound in recent years. In 1904, however, and for some years previous to that time only about 4 or 5 cents a pound was obtained on the average.

DISTRIBUTION IN USE.

The one standard domestic use of the One-Sucker type of tobacco is in the manufacture of twist, for which its toughness and medium strong flavor and body render it particularly adaptable. A large portion of the medium-sized, finer textured, leaf of this district is used for twist purposes. It is particularly adapted for this purpose in that it has the required toughness of leaf and is generally of medium body and strength. It is about midway between the light, rather characterless Burley and the very strong heavy types grown farther west in the Clarksville and Paducah districts.

The standard and most important export demand of the One-Sucker type of tobacco is for rehandling purposes in preparation for shipment to Africa, the West Indies, and a number of the Spanish-American countries of Central America and South America. In this trade, as finally utilized, much of the tobacco is retailed in the leaf. Length is one of the prime attributes for this class of trade, and since it is not stemmed the manufacturer experiences no loss from the large proportion of stem. For this purpose the leaf should be from 25 to 30 inches long, and the longer it is the better price it will usually bring. This rehandling consists in artificially enriching the leaf by treating it with various materials such as glycerin or vaselin and in blackening it by steaming and subjecting it to very heavy pressure in prizing. The treated tobacco is packed in tierces, boxes, or bales of various shapes and sizes convenient for transportation, often some distance inland, by animal power. A number of large plants for rehandling tobacco of the type just described, probably representing some 80 per cent of the total business of this class in the country, are located in Louisville.

The manufacture of domestic twist and the rehandling or export trade probably absorb about two-thirds or 20,000,000 pounds of this One-Sucker type of tobacco annually. The other 10,000,000 pounds is uncertainly divided among a number of miscellaneous domestic and export demands very difficult to classify accurately. An approximate estimate of the distribution in use of the One-Sucker type is presented in Table XXV.

TABLE XXV.—*Estimated distribution in use of the One-Sucker type of tobacco.*

Use.	Pounds.	Use.	Pounds.
Domestic:		Export:	
Twist	8,000,000	Rehandling, Africa, etc	12.000,000
Plug	5,000,000	Miscellaneous	3.000,000
Granulating	2,000,000		
		Total	30,000,000

A large portion of the dark tobacco sold in Louisville is of the One-Sucker type from this district, shipped in mostly by country dealers and speculators. The areas covered by the subdivisions of the One-Sucker air-cured type are shown on the map (Pl. II, in pocket).

VIRGINIA "SUN-CURED" TOBACCO.

Several of the counties of middle Virginia just north of the James River produce a type of tobacco known to the trade as "Sun-Cured," which is probably in the nature of a development from tobacco growing as it was practiced in the early days in the York and Rappahannock River sections of the State.

METHOD OF CURING AND GENERAL CHARACTERISTICS.

The name "Sun-Cured" as now applied to the type as a whole is really a misnomer so far as indicating any special method of sun curing is concerned. In the typical sun-cured product the tobacco is scaffolded in the open air or sun near the curing barn and is allowed to remain on the scaffold crowded rather closely together for five or six days until thoroughly yellowed. The sticks of tobacco are then spread apart somewhat so that the air may pass between the plants in order to prevent damage to the lug leaves from sweating, and the tobacco is then allowed to remain on the scaffold three or four days more until well under way in the curing process. It is then placed in the barn and the curing process finished as with any air-cured tobacco. This exposure to the sun is thought to sweeten and improve its flavor for chewing purposes. As a matter of fact, however, owing largely to the increased cost of labor and greater expense in handling, the typical sun-curing process is now but little practiced and tobacco in the Sun-Cured district is, for the most part, just an air-cured tobacco, as is Burley or Green River or the cigar types.

Such special qualities as the so-called "Sun-Cured" tobacco possesses in contradistinction from other air-cured types are really due, therefore, to soil and climatic modifications, methods of cultivation, and seed rather than to the process of curing. The seed used in the Sun-Cured district, however, is practically the same as that used in the other dark-tobacco districts of Virginia, Kentucky, and Tennessee. Figure 35 shows the tobacco "sunning" on the scaffold near the open south side of the curing barn. In case of rain it is quickly removed to the shed.

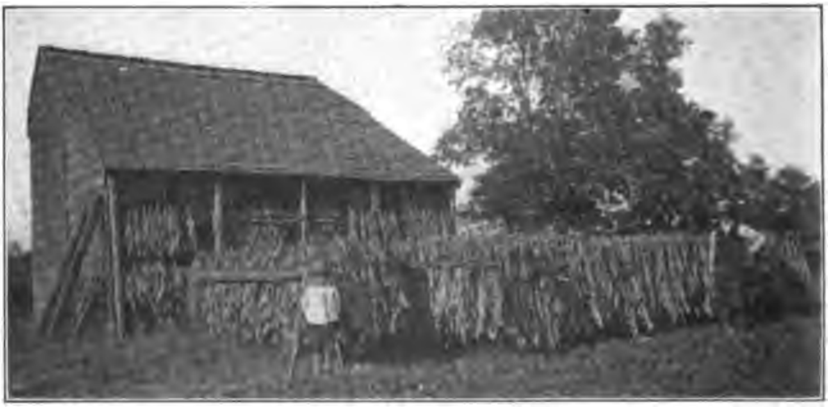

FIG. 35.—Sunning tobacco in the Virginia Sun-Cured district, Caroline County, Va.

USES OF "SUN-CURED" TOBACCO.

"Sun-Cured" tobacco practically all goes into domestic consumption in the form of flat plug, both the wrapper and the filler being of this type. It makes a sweet but rather strong chew, much in favor by chewers, especially in Virginia and North Carolina.

Nearly all the "Sun-Cured" tobacco is manufactured in the factories at Winston Salem, N. C., and at Richmond, Va.

DISTRIBUTION OF ACREAGE.

In former days "Sun-Cured" tobacco was extensively grown in several of the south side counties of the State, and a little "Sun-Cured," or, more correctly speaking, air-cured, tobacco is still produced here and there in the eastern portion of the dark-fired and flue-cured districts of Virginia (mostly in the section from Clarksville, in Mecklenburg County, to Petersburg), and also in the Winston Salem section of the flue-cured district in North Carolina. The production is now confined principally, however, to the counties near Richmond on the north side of the James River, distributed approximately as shown in Table XXVI.

TABLE XXVI.—*Estimated annual production of "Sun-Cured" tobacco in Virginia, distributed by counties.*

Counties.	Pounds.	Counties.	Pounds.
Caroline	3,000,000	Fluvanna	500,000
Louisa	2,500,000	Other counties	750,000
Hanover	2,000,000		
Goochland	1,250,000	Total	10,000,000

PRICES AND GRADES.

The popularity and demand for "Sun-Cured" tobacco has seemed to be increasing for the past few years, and it has brought fairly good prices—in recent years usually a little above the average for the dark-fired district of Virginia. The average prices obtained by farmers in the five-year period 1905 to 1909 has been from 8 to 10 cents a pound. Some crops, of course, average very much more, sometimes double these figures, and good plug wrappers frequently bring from 25 to 40 cents a pound, although of course these highest grades constitute but a small percentage of the crop. Under the influence of better prices the acreage of "Sun-Cured" tobacco in recent years has tended to increase somewhat, and the crops of 1909 and 1910 were probably close to 10,000,000 pounds each year. At the State fair held at Richmond, Va., in October, 1910, members of the Richmond tobacco trade offered special premiums for the best samples of sweet air-cured tobacco produced in several new sections as well as in the regular Sun-Cured territory itself, with the purpose of increasing the production. Actual future expansion will probably depend more upon prices paid than on any other factor.

In assorting "Sun-Cured" tobacco, farmers generally make fewer grades than with other Virginia types—often but two grades, classed as leaf and lugs—unless there are wrappers present in sufficient quantity to make it worth while to pick them out. From the buyer's standpoint the important grades are fillers and wrappers of varying character and value. "Sun-Cured" tobacco is practically all marketed loose through the auction warehouses at Richmond.

The Sun-Cured manufacturing district of Virginia is outlined on the map (Pl. I, in pocket).

PERIQUE TOBACCO.

Out of the attempts to produce tobacco for export on the rich river lands of Louisiana in the early days when it was a French colony a peculiar method of manipulation in curing the tobacco that is unique and distinctive was finally introduced among the Arcadians of a community in St. James Parish.

Although the production of Perique is so small as to make it of but slight importance commercially, the process is so unique as perhaps to warrant a brief description of the manner in which this tobacco is produced.

METHODS OF PRODUCTION.

The tobacco is grown on the more elevated and drier portions of the rich Mississippi alluvial soil in the heart of the sugar-cane and rice country in St. James Parish, La. The type of seed used does not seem to be important, but the large, heavy, dark varieties are best. Burley was tried a few years ago by some of the growers, but it proved distinctly unsuitable, as it would not blacken properly and gave up its juices too freely under pressure.

The land is heavily bedded in rows about 5 feet apart in preparation for planting and about 2,500 plants are set to the acre. The tobacco is generally grown continuously on the same land year after year, but as the crop is harvested about the last of June, cowpeas are grown during the remainder of the year and are turned under in preparation for the next crop. About 200 pounds of cottonseed meal per acre are also generally used as a fertilizer. Topping and suckering are practiced about as in the dark-tobacco districts.

In harvesting, the entire plant is cut and hung from the wires stretched across the barn by suspending each plant separately by means of a nail driven partly into the butt of the stalk at an appropriate angle.

In about 10 days most of the leaves are sufficiently cured to strip, and the stripping must be done at the right stage, that is, while the web of the leaf is brown and the midrib is still green for about two-thirds of its length. The stem is removed and the leaf split in half and made up into large twists about a foot long, weighing approximately 1 pound each. About 50 of these twists in very soft order are then packed in strong pressing boxes 11 inches square and 16 inches high.

The tobacco is then placed under very high pressure by means of lever presses. Heavy weights, usually of stone, are applied at the long end of the lever in order to give a steady, uniform pressure, such as could not be obtained with a screw, the object being to start the juices which ooze from the leaves, black and sticky. The pressure is so regulated as merely to start the sap to oozing, but not to make it run from the boxes, because it is desired that it be reabsorbed. This process gives to Perique tobacco its black, gummy appearance when finished.

In order that this process may proceed uniformly, the boxes are opened every day or two for two weeks, and the twists are loosened so as to allow the air and moisture to reach all parts and so that the juices will be pressed out and reabsorbed uniformly throughout the entire twist. At least once during this period of "working," as it is called, the twists are opened up fully and any unchanged or dry leaves are placed on the outside of the twist and dampened; sometimes a little petune, usually rum, is blown over each layer of twists as they are packed back in the boxes.

At the end of this period of "working," the tobacco is ready to "lay by," as it is called. A considerable shrinkage of volume has by this time taken place, so that the contents of three boxes can be put into two. The pressure from the levers is renewed but is made not quite so heavy as at first and allowed to remain for a period of several months, during which time the tobacco mellows and ages and acquires the characteristic aromatic fragrance peculiar to Perique. The tobacco is ready for use the following February or March, or about eight months after harvest. The yield of cured tobacco after it has been through this process (minus the stems, it will be noted) is 400 to 500 pounds to the acre.

Until recent years nearly all Perique tobacco was put up into cylindrical rolls or carottes, as they are called, weighing either 4 pounds or 1 pound each. These rolls were made by carefully rolling the required weight of tobacco in pieces of strong cloth and then winding with strong rope cord under heavy strain by means of an ingenious windlass device. This rope winding is allowed to remain for several days or until the carotte is to be sold, when the rope and cloth covering is removed and an appropriate paper or other cover with revenue stamp is put in its place. This heavy pressure from the rope winding serves to compact the tobacco so that it will not dry out and puts it in good shape to whittle or shave off the end of the roll into fine cut for either cigarette, smoking, or chewing purposes. Figures 36 and 37 illustrate various features of this process of handling Perique tobacco.

Only a small portion of the Perique crop is now put up in carottes in this manner, however, and that portion mostly for local trade. The bulk of the crop is sold in the form in which it comes from the curing presses to regular manufacturers. For shipment to this class of trade the compacted juicy twists are packed and prized into whisky barrels, about 500 pounds to the barrel. Orders for

Perique in this form are usually placed by manufacturers some time in advance, often before the crop is planted.

Whether or not this peculiar method of curing tobacco was really invented in its essentials by the Arcadians, as some think, seems uncertain. The writer is inclined to believe that it was not. At any rate, it is known that the natives of some Central American and South American countries have for years been putting up tobacco in twists after subjecting it to heavy pressure by windlass or other devices. Many European manufacturers put up coil tobacco, blackened by heavy pressure and absorbed juices, possessing much the appearance and aroma of Perique.

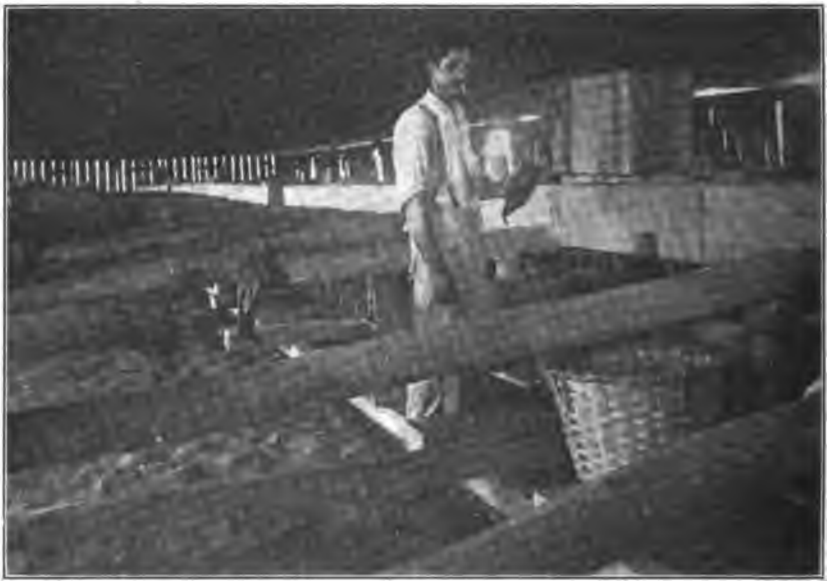

FIG. 36.—Working (loosening and aerating) the twists of Perique tobacco during the pressing process, St. James Parish, La.

USES OF PERIQUE TOBACCO AND LOCATION OF AREA.

The production of Perique tobacco is considered by the Bureau of Internal Revenue to be in the nature of a manufacturing process and all Perique producers are classed as manufacturers and registered as such, although they pay the tax on only a small portion of the product. The larger portion of their production is sold to other manufacturers as material in process of manufacture before payment of the tax.

The total production of Perique is small, amounting to about 200,000 pounds annually, as indicated by the internal-revenue figures and by the estimates of the growers. More than 50 Perique manufacturers are usually registered on the internal-revenue books.

Manufacturers mostly use Perique in small quantities in fancy smoking-tobacco mixtures to give them richness and aroma. Considerable Perique is used locally in the form of fine cut for chewing and as shaved from the ends of the carottes for rolling into cigarettes. Cigars of some brands have a few strands of Perique in them to add to the body and richness of the smoke.

The Perique district is principally confined to a small section of St. James Parish on the east side of the Mississippi River and immediately back from the river from Lutcher to Convent, a distance of about 12 miles. More than half the total production is centered in the Grand Point district about 3 miles from the river and back of Hester station. Grand Point is not a projection into the river, as might be supposed, but rather a body of land a little lighter in texture and slightly above the general flat level, jutting into low, swampy land back from the river. Here in a small section, perhaps not over 1,000 acres in extent, reside most of the Perique planters, each growing usually from 5 to 15 acres of tobacco, to which they devote practically their entire attention. They are nearly all Arcadian French—a very kindly and hospitable people.

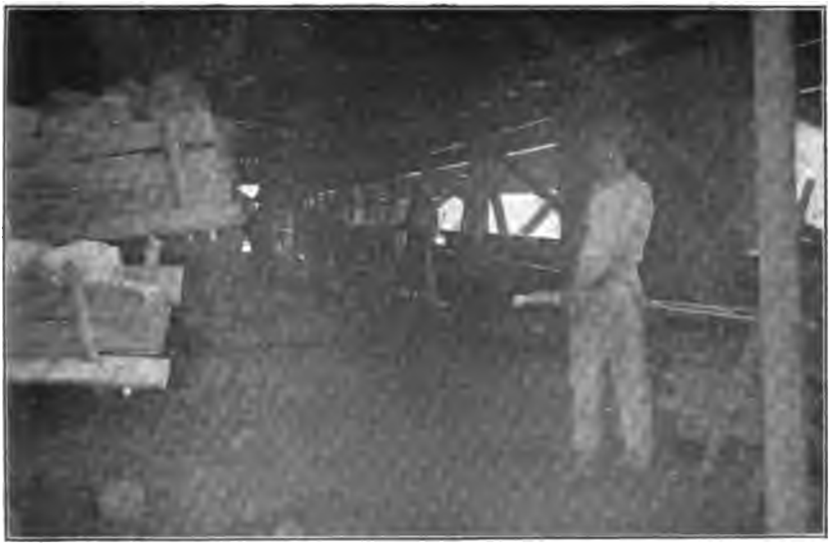

FIG. 37.—Winding the carotte with rope, which is left very tight by the windlass arrangement, Perique tobacco district, St. James Parish, La.

Perique tobacco in carottes now sells at retail for about 50 cents a pound. In whisky barrels to dealers, however, the prices vary considerably and are of course subject to agreement, but it is understood to run from about 25 to 30 cents a pound. In former years prices were much above this and carottes sold for $1 a pound.

BRAZILIAN TOBACCO.

In the western part of Williamson County, Tenn., in the vicinity of College Grove, Triune, and Allisona, there is a small section that has for a number of years produced a few hundred thousand pounds yearly of what is known to the trade as Brazil smoking tobacco.

Locally this is thought to be the best of smoking tobaccos. It is mostly put up in granulated form. Its popularity has waned in recent years except locally, and very little has been grown in the past few years. Under the influence of the high prices even for the low grades of Burley, the attention of growers has turned mostly to experiments in growing the Burley type.

Brazilian tobacco, in general appearance and habits of growth, resembles Cuban tobacco more than any of the manufacturing or export types which we have described.

RÉSUMÉ, WITH STATISTICS OF ALL TYPES.

Table XXVII is in the nature of a résumé of the actual production of tobacco in the United States in 1909 as estimated by the crop-reporting board of the Bureau of Statistics of the United States Department of Agriculture. The division into types does not in every case follow that laid down in the preceding pages of this bulletin, but it is sufficiently similar to enable any reader to fit the two together without difficulty.

The most important modifications in classification are the grouping of the Stemming and the Green River districts together as one district, calling them the Henderson or Stemming district. No mention is made of a One-Sucker type or district, but two of its component parts, the upper Green River and upper Cumberland sections, are mentioned as separate districts. The southern Indiana section of the One-Sucker district is not specifically mentioned, but it is included in the production mentioned as "scattered" at the bottom of the table, which has been slightly rearranged to make it conform better to the purpose in view. The price averages of two dates 5 years apart, December 1, 1904, and December 1, 1909, have been added for comparison as a matter of general interest. The actual total production of each type was not made a matter of special record at the earlier time.

TABLE XXVII.—*Official estimates of the production of tobacco and yield per acre by types in the United States in 1909, with a comparative statement of the farm price on December 1, 1904, and December 1, 1909.*

Type and district.	Acreage.	Yield per acre.	Production.	Comparison of farm prices per pound.		Value.
				Dec. 1, 1909.	Dec. 1, 1904.	
Cigar types:	*Acres.*	*Pounds.*	*Pounds.*	*Cents.*	*Cents.*	
New England	18,100	1,638	29,655,000	15.9	21.6	$4,709,500
New York	6,000	1,175	7,050,000	8.0	10.0	564,000
Pennsylvania	31,200	985	30,732,000	9.0	8.9	2,765,880
Ohio, Miami Valley	55,000	900	49,500,000	9.5	7.5	4,702,500
Wisconsin	31,500	1,180	37,170,000	9.2	7.8	3,419,640
Florida and Georgia	6,600	707	4,665,000	34.0	28.8	1,586,100
Totals and averages (cigar types)	148,400	1,070	158,772,000	11.2	....	17,747,620
Export and manufacturing types:						
Burley district	255,000	960	244,800,000	13.4	9.1	32,803,200
Virginia dark-fired district	70,000	840	58,800,000	7.8	6.1	4,586,400
Clarksville and Hopkinsville district	90,000	740	66,600,000	8.0	5.8	5,328,000
Paducah or Western district	82,000	675	55,350,000	7.3	4.8	4,040,500
Henderson or Stemming district (including lower Green River)	92,000	770	70,840,000	6.8	4.1	4,817,120
Upper Green River (One-Sucker type)	20,000	720	14,400,000	6.2	4.8	892,800
Upper Cumberland (One-Sucker type)	11,000	760	8,360,000	6.6	4.7	551,760
Virginia "Sun Cured"	11,000	835	9,185,000	8.4	7.4	471,540
Flue-cured district:						
Old Belt	189,000	640	120,960,000	9.9	8.6	11,975,040
New Belt	164,500	650	106,925,000	8.3	8.4	8,874,775
Maryland and eastern Ohio export districts	28,600	735	21,021,000	8.3	6.4	1,744,743
Perique, Louisiana	400	550	220,000	37.0	21.5	81,400
Scattered	18,400	....	13,124,000	11.4	....	1,504,467
Totals and averages (export and manufacturing types)	1,031,900	766	790,585,000	9.8	....	77,971,745

According to these estimates the actual production in 1909 of all the export and manufacturing types was 790,585,000 pounds. This statement is to be compared with the average estimates already given, amounting to 741,200,000 pounds, as derived almost entirely from private sources. A large part of the actual excess of 1909 over the average estimates was in the Burley type, which was well above normal for that year. The estimate of Burley in the district of 244,800,000 pounds in 1909 accounts for about 30,000,000 pounds of the 49,000,000 pounds difference, and undoubtedly a large portion of the 13,124,000 pounds scattering production of unnamed types was also Burley.

For purposes of easy comparison the estimates of the average production of the various export and manufacturing types as presented in tables throughout the general discussion in this bulletin are shown in Table XXVIII.

TABLE XXVIII.—*Estimated average annual production of tobacco in the United States.*[1]

Name of district or type of tobacco.	Pounds.
Burley	215,000,000
Virginia dark-fired	52,000,000
Clarksville and Hopkinsville	70,000,000
Paducah	60,000,000
Henderson or Stemming	35,000,000
Green River	35,000,000
One-Sucker (including southern Kentucky or upper Green River, upper Cumberland, and southern Indiana)	30,000,000
Virginia "Sun Cured"	10,000,000
Maryland and eastern Ohio export	21,000,000
Flue-cured, Old Belt	120,000,000
Flue-cured, New Belt	95,000,000
Perique	200,000
Total export and manufacturing types	741,200,000
Add cigar types (average production from Table XXVII)	158,800,000
Normal production of tobacco (all types) in the United States at the present time	900,000,000

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[1] Based on the estimates by districts as presented in this bulletin.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 245.
B. T. GALLOWAY, *Chief of Bureau.*

INVESTIGATIONS OF THE POTATO FUNGUS PHYTOPHTHORA INFESTANS.

BY

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Professor of Plant Pathology, University of Vermont.

[In cooperation with the Vermont Agricultural Experiment Station.]

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 20, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 245 of the series of this Bureau the accompanying technical paper by Dr. L. R. Jones, Mr. N. J. Giddings, and Prof. B. F. Lutman, entitled "Investigations of the Potato Fungus Phytophthora Infestans."

This potato fungus causes the most destructive disease known to this important crop and has thus far baffled attempts at its complete control, owing probably in part to ignorance of its entire life history. This paper embodies not only a consideration of the main facts in the development of the disease and of the methods for its control by spraying and other standard practices, but also contributes some important new facts as to the development of resting spores by the fungus. Attention is further directed to the possibilities of control through the use of disease-resistant varieties, and a laboratory method is here developed for promptly testing the relative disease resistance of potato tubers.

The work has been done by Dr. Jones as a collaborator of the Bureau of Plant Industry, in cooperation with the Vermont Agricultural Experiment Station, with the assistance of Mr. Giddings and Prof. Lutman and of the workers mentioned in the footnote on the first page of the text. The need of such an investigation had long been felt and it was undertaken in this manner because of the long experience of Dr. Jones with this problem and because the disease is of much more frequent occurrence in Vermont than in the vicinity of Washington. The bulletin forms part of a series of studies on potato diseases and disease resistance in progress in this Bureau under the general direction of Mr. W. A. Orton.

The illustrations submitted are essential to an understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—719.

INVESTIGATIONS OF THE POTATO FUNGUS PHYTOPHTHORA INFESTANS.[1]

INTRODUCTION.

These studies upon the potato fungus *Phytophthora infestans* have been the outcome of apparent need coupled with evident opportunity. For both economic and scientific reasons there is need of a fuller understanding of the life history of this fungus and its relations to the host plant, while the frequency of its occurrence in Vermont has offered favorable opportunity for carrying on such investigations. No other of the staple farm or garden crops of this country is subject to such extreme variations in production as the potato, because of disease of one or another kind. This is doubtless in part due to the fact that it has been so recently brought into culture and under conditions so different from those of its natural habitat.[2] Moreover, no other of these diseases equals in possible damage the fungus under consideration. In its worst form (that is, when conditions are especially favorable to the disease) the destruction of the potato foliage by the late-blight may be complete within a few days after its appearance and that of the tubers by the associated "rot" may be no less appalling. The terrible Irish famine of 1845 was due to the almost total loss of the potato crop of Ireland from this disease the preceding summer. In this country the last general outbreak was in the years 1901–1903. In 1901 Jones and Morse (1902, p. 210)[1] estimated that 65 to 95 per cent of the unsprayed potatoes on the Vermont experiment station farm showed rot following late-blight and that on August 23, 1902, the plants in two-thirds of the fields around Burlington, Vt., had died from this cause. In New York State it was estimated by Stewart of the Geneva station (Stewart, Eustace, and Sirrine, 1903, p. 252) that the loss in 1903 was 50 bushels per acre on the average, meaning a loss of nearly 20,000,000 bushels on the 400,000 acres of potatoes planted in that State that year. Morse (1909), of the Maine experiment station, estimated that 25 to 75 per cent of the crop of Aroostook County, Me., rotted in September and October, 1909, and that the loss was several hundred thousands of dollars. It was shown a half century ago that this blight and rot are caused by the fungus under consideration, but we are in ignorance as to the life history of the parasite, especially as to how it overwinters and what determines its sudden and usually unexpected outbreaks and the inception of an epidemic. The present publication aims to summarize what was previously known regarding the fungus and to record in detail the progress that has been made in the present studies toward a fuller understanding of its life history and its relations to the host. Before doing so it will be desirable for practical reasons so to describe the occurrence and appearance of the disease as to preclude its confusion with any of the other potato maladies.

---

[1] The studies upon which this publication is based have been in progress for a number of years. The writers wish to acknowledge their indebtedness for advice during the progress of the work to W. A. Orton and Erwin F. Smith, of the United States Department of Agriculture, as well as to William Stuart, now of the Department of Agriculture, formerly horticulturist of the Vermont Agricultural Experiment Station. Valuable assistance was rendered by W. M. Gambell in the early morphological studies; by H. A. Edson in the later cultural work, especially in the devising of new culture media; and by F. V. Rand and C. R. Orton in the determinations of disease resistance. The responsibility for the general direction of the work fell upon the senior writer. The larger part of the detailed study was made by Mr. Giddings. His removal to the West Virginia Agricultural Experiment Station early in 1909 left the later responsibility for this upon Prof. Lutman.

There are several matters upon which further study would be desirable before publication, but the removal of the senior writer to Wisconsin, following that of Mr. Giddings to West Virginia, has led to the decision to make the publication in its present form as best conducing to further progress. The authors therefore ask that it be accepted as a preliminary report of progress and hope that its lack of finality at certain points, especially as to resting-spore production and as to what constitutes disease resistance, may stimulate others to aid in the solution of the problems involved.

This report is issued simultaneously by the Vermont Agricultural Experiment Station as Bulletin No. 168 of that station.

[2] For a fuller discussion of this point, see Jones, L. R., "The Diseases of the Potato, etc.," Transactions of the Massachusetts Horticultural Society, pt. 1, 1903, pp. 144–156. Also, Jones, L. R., "Disease Resistance of Potatoes," Bulletin 87, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905.

CHARACTERS AND OCCURRENCE OF THE LATE-BLIGHT AND ROT CONTRASTED WITH OTHER POTATO DISEASES.

Several other diseases of the leaves and the tubers of the potato have some symptoms resembling the blight of the foliage and the rot of the tubers caused by the fungus *Phytophthora infestans*. In consequence there has been some confusion in the discussion of potato diseases even by scientific men, and discrimination on the part of the practical grower is still more difficult. As a guide to the recognition of these diseases a list of the various maladies reported for this country is here given with such a brief characterization of each as will best serve to distinguish it from the late-blight or the rot due to Phytophthora. While these helps may not suffice to enable one unfamiliar with the subject to recognize separately each of these potato maladies, it should be comparatively easy from the descriptions and the accompanying illustrations to distinguish the attacks of *Phytophthora infestans.* The disease caused by this fungus involves both the aerial and the subterranean parts of the potato plant. In this country the malady is commonly termed blight (or late-blight) as it appears on the foliage and rot (or dry-rot) as it appears in the tubers.

---

[1] Bibliographic citations in parentheses throughout the text of this bulletin refer to the "Index to literature," pp. 88–93, in which titles are arranged alphabetically by authors, separate works by the same author being placed chronologically.

CHARACTERS OF THE LATE-BLIGHT AND ROT.

LATE-BLIGHT OF THE FOLIAGE.

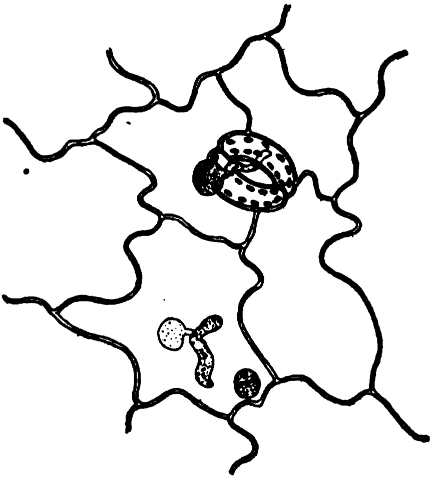

FIG. 1.—Sketch showing the penetration of a potato leaf by germ tubes of *Phytophthora infestans* through the breathing pore and the cuticle. Surface view. (After Ward.)

The late-blight rarely appears on the foliage (see Pl. I) until the plants have passed the flowering stage. Indeed, it has not been observed to precede blossoming except where an early crop infects the plants of a late crop growing near by. Observations under natural conditions and inoculations also have proved that infection in this way may occur at any stage in the plant's development. At any time after the blossoming stage, if the weather conditions are favorable and the fungus is present, the disease may appear as purplish black or brownish black areas on the potato leaves. These spots are especially liable to show on the lower leaves of the plant, although one need not for this reason necessarily accept the suggestion of Clinton (1905, pp. 307–311) that there has been infection from the soil. This is, however, an interesting possibility. The diseased areas commonly appear first near the tip or margin of the leaf, although they may subsequently occur anywhere upon the leaf, petiole, or even on the stem. Infection is apparently primarily conditioned upon the accumulation of moisture from favoring dew or rain, which gives opportunity for the spores to germinate and push their germ tubes into the tissues. (Figs. 1 and 2.) If one examines blighting leaves carefully while they are still moist on a dewy morning or after a shower, a delicate growth of the fungus is perceptible as a powdery bloom on the under side, but less often on the upper, where the diseased area borders the

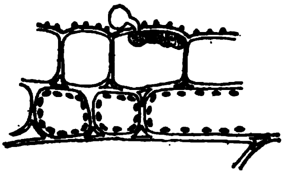

FIG. 2.—Sketch showing the penetration of the epidermal cell of a potato leaf by a Phytophthora germ tube. Sectional view. (After Ward.)

green. This aerial growth bears the spores which serve to carry the infection to healthy leaves (fig. 3).

A more detailed examination of the progress of the malady will now be worth while. In the field it does not usually attract the attention of the casual observer until the upper leaves are attacked and blackened. This stage really marks the climax or even the closing stages of the epidemic and not its inception. The beginnings

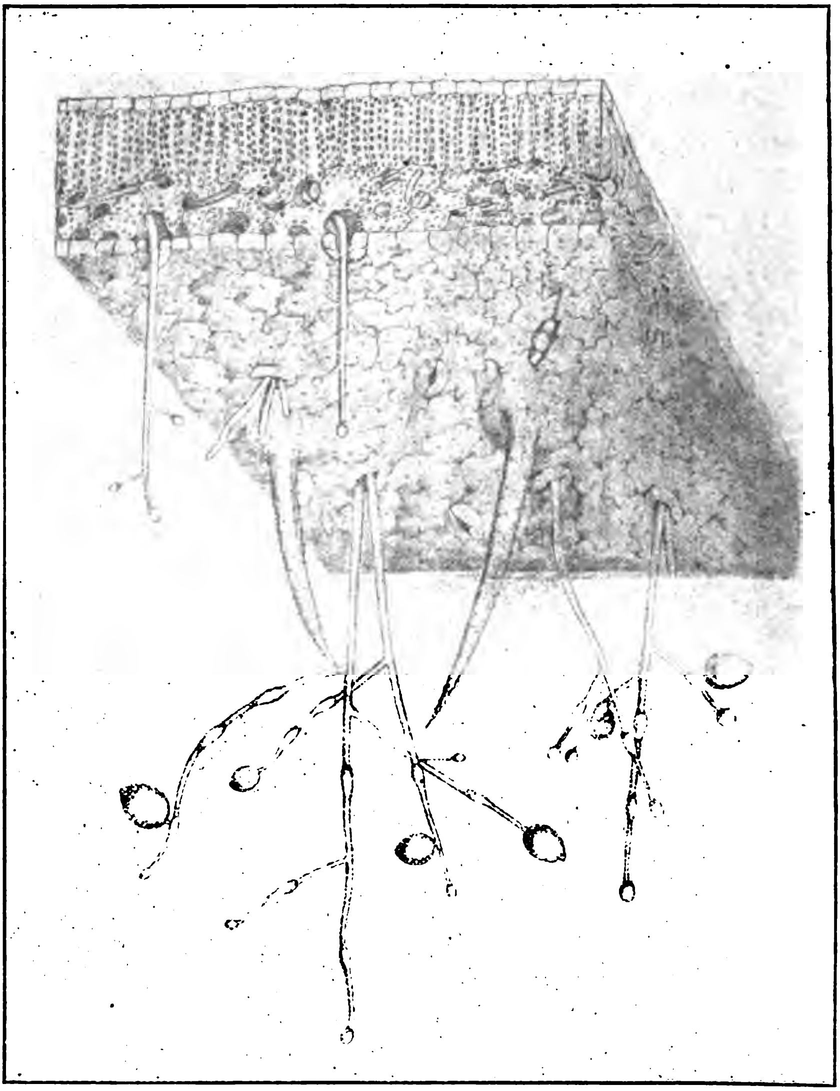

FIG. 3.—Diagrammatic representation of a square cut from a potato leaf infested with *Phytophthora infestans,* showing the fungus emerging through the breathing pores and the successive stages in the development of conidiophores and conidia.

antedated this by days or even weeks. The first external symptoms begin to show in about five days, on the average, from the infection of a healthy leaf, as noted by De Bary (1863) and frequently verified by the writers (Pl. I). The invaded area on the leaf takes on a water-soaked appearance, pales somewhat, then wilts and blackens. The size of the spot increases with a rapidity determined by weather conditions; if favorably moist the entire leaf will be killed in from one to four days. If the weather is dry the tissues curl up and shrivel soon after death; if moist, as is the more usual thing when the disease is prevalent, the blighted leaves become limp and soon rot, emitting a characteristic strong odor. The fact that after infection only about five days are required for the appearance of a new crop of spores explains how, when conditions best favor, it is possible within a week after the appearance of the first diseased leaves to have the foliage of all the neighboring plants stricken. As a matter of fact the malady is usually in the incubation stage two weeks or more from its early appearance upon scattered plants before it becomes generally epidemic over the field. When the epidemic stage is reached, if favored by moist weather, the entire foliage is blighted in a period of time almost incredibly short.

ROT OF THE TUBERS.

When the tops have been thus blighted (Pl. II) a varying percentage of the tubers usually show the rot, which ordinarily appears first on the upper sides of the tubers lying nearest the surface of the soil. In the earliest stages it appears as a slight brownish or purplish discoloration of the skin, and if the soil is moist the underlying tissues may be softened. In a damp, heavy soil this rotting usually spreads rapidly over the surface and proceeds inward so that the entire tuber browns and decays before harvest, constituting what is termed the "wet-rot." This is, however, as shown by Delacroix (1903) and others, largely due to the secondary invasion of such tubers by bacteria and fungi. In drier soils or seasons the progress of the disease is slower and the brown stain extends only to a depth of one-eighth to one-fourth of an inch. Meanwhile, owing to the drying out of the dead cells, the surface of the tubers wherever invaded becomes slightly sunken and of a darker color, often purplish black in the white-skinned varieties. This appearance, known as the "dry-rot," may be much in evidence at the time of harvesting, or it may show but little then and tend to develop during the first month or two of storage. If the tubers are kept in a properly cool, dry cellar this dry-rot is soon checked and they may pass the winter in this state, the superficial stain rarely extending to a greater depth in the flesh than one-fourth to one-half of an inch.

OCCURRENCE OF THE LATE-BLIGHT AND ROT.

This disease is common in the Northeastern States, especially in northern New England and New York and also in the adjacent parts of Canada. Farther south and west it is either unknown or more sporadic, unless it be on the northern Pacific coast regions. The accompanying map (fig. 4), prepared under the direction of W. A. Orton, indicates the occurrence of this fungus as based on all available records. The conclusion seems justified that the late-blight has been at one time or another introduced with seed potatoes or otherwise into practically all of the potato-growing sections of the country and that under favoring local conditions, moist weather without too great heat, it will temporarily develop anywhere. For example, the most destructive epidemic of the last decade in the United States was in 1902–1904 in the northern Mississippi Valley, when the potato sections of Michigan, Wisconsin, and Minnesota were swept for two successive years by the late-blight and rot. Before that for 20 years the fungus had not been observed there and since then it has apparently disappeared again, doubtless owing to the fact that the summers are usually too dry and warm to permit its rapid spread. On the other hand, in the Northeastern States the midsummers are typically moister and cooler, and here the Phytophthora finds conditions favorable for some development almost every year and for a pro-

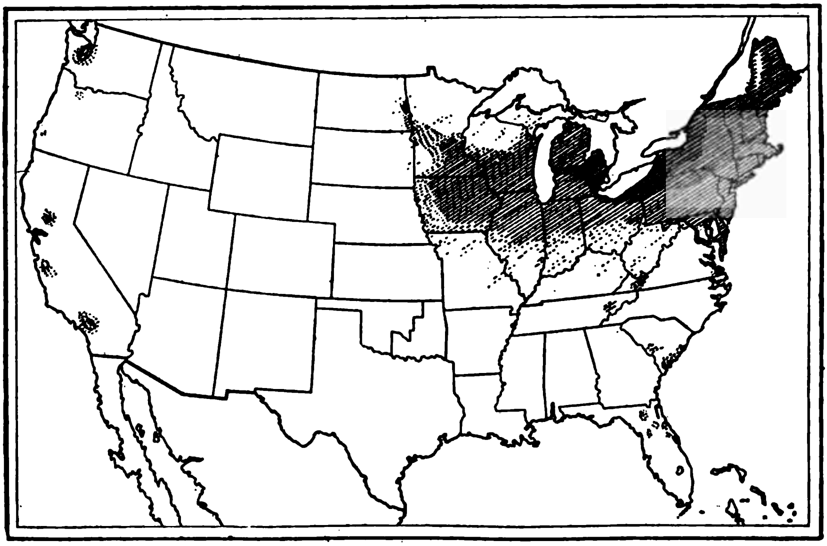

FIG. 4.—Map of the United States showing the distribution of the Phytophthora potato disease. The sections where the disease is the more prevalent are indicated by the heavier shading. Doubtless further investigation will extend the range westward along the northern border.

nounced epidemic perhaps two years out of five.[1] It seems a fair presumption that the occasional outbreaks of this disease southward and its introduction westward are the direct result of the frequent importation of the fungus along with seed tubers obtained from these northeastern regions.

OTHER DISEASES OF THE POTATO IN AMERICA.

Some of the other maladies known to occur in America from which this Phytophthora disease, or late-blight and rot, must be distinguished are early-blight, leaf-blotch, arsenical poisoning, sun scald, tip-burn, bacterial wilt and rot, black-leg, leaf-curl, Fusarium wilt and rot, scab, wart disease, internal brown-spot, and soft-rot.

Early-blight.—A widespread disease of the foliage caused by the fungus *Alternaria solani* (E. and M.) J. and G., is known as early-blight. It appears as small, irregular, sharply defined black spots on the leaves, marked by faint, target-board-like, concentric ridges. These begin to show earlier than the late-blight and in drier weather; indeed, it is rather characteristic of dry, warm soils. The progress of the disease is slow, but as the spots increase in number and size they may ultimately destroy the entire foliage, either alone or in combination with tip-burn and other maladies.

Leaf-blotch.—Another leaf-spot disease caused by a fungus, *Cercospora concors* Casp., has been observed in America (Jones and Pomeroy, 1907, pp. 236–256) in only one State (Vermont), but is widespread in northern Europe. It so closely resembles the early-blight that it may have been confused with it and occur more widely than is now known in this country. The diseased spots are larger and less sharply defined than with early-blight, without concentric markings, at first merely paler green, then turning yellow or brown and dying. The fungus is apparent as a purplish gray growth most evident on the lower surface. At certain stages it may easily be mistaken for the Phytophthora blight.

Arsenical poisoning.—The poisoning of potato leaves by Paris green or other arsenical sprays directed against insects is very common and often confused with the fungous blights. In severe cases the entire foliage is killed outright. More usually the poisoning is only local on the plant and appears as metallic-brown or blackish spots, centering as a rule about flea-beetle punctures or other breaks in the epidermis. Concentric target-board markings may occur, and often visible deposits of the poison near the center of the spot bear witness to its cause.

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[1] On the relation of weather to occurrence of Phytophthora, see Ninth Annual Report of the Vermont Agricultural Experiment Station, 1895, pp. 66–71; also Bulletin 159, Vermont Agricultural Experiment Station, 1911.

Sun scald.—With potatoes, as with other tender foliage, sun scald occurs when bright, hot weather follows suddenly upon a moist, cloudy period. The scalded areas occur especially between the veins and near the extremities of the leaflets. It is commonest during the period of most rapid foliage development, i. e., before blossoming.

Tip-burn.—The name tip-burn is well applied to the drying and death of the leaves beginning at the tip and margin as a result of protracted dry heat. The dead areas blacken, crisp, and uproll. Insect or other injuries aggravate the trouble. It is commonest after the plants have passed their greatest vigor, i. e., after blossoming.

Other leaf-spot diseases.—Two types of leaf spotting occasionally occur, other than those already noted. The first is due to the slow dying and drying out of the tissues surrounding any wound in the leaf (Sturgis, 1895, p. 132). It is, in a way, comparable to tip-burn and may occur at the same time. As with tip-burn, such dead tissues are usually soon invaded by saprophytic fungi, such as *Alternaria fasciculata* and *Cladosporium* spp.

A second type of leaf spotting may occur and is sometimes quite prevalent, the cause of which is not understood. It is evidently the same malady as described by Appel and Kreitz (1907) and other European pathologists as "Dürrfleckigkeit." The blackening first appears, as a rule, along the smaller veinlets, which fact serves to distinguish the disease from early-blight; but the spotting, especially in the later stages, may occur between the veins, which makes the resemblance to typical early-blight so close that microscopic examination may be necessary to distinguish them. These spots are free from fungi in their earlier stages and are later occupied only by the common saprophytes. Appel has suggested that bacteria attacking the base of the plant may be responsible for this leaf spotting, but our own observations lead us to regard the malady as nonparasitic. This interpretation is favored by the fact that it may appear only on single plants or on certain varieties in a field without association with observable root or stem lesions and without showing a tendency to spread to neighboring healthy plants.

Brown-rot.—A disease known as brown-rot, attacking not only the potato but the tomato and other solanaceous plants, as shown by Smith (1896), is caused by bacteria (*Bacillus solanacearum* Sm.). The organisms invade the vessels of the stem, browning them and causing the base of the stem to take on a dull, muddy-green color and the foliage to wilt and die. The young tubers are also invaded, the vascular ring blackened, and a soft rot ultimately developed. If invaded stems or tubers in the earlier stages are cut across, the bacterial growth which plugs the darkened vessels may ooze out as small gray beads. This disease is most common in the Southeastern States bordering the Atlantic.

Black-leg.—A disease much more widespread than brown-rot, probably occurring in all of the older potato-growing regions, is known as black-leg. It is characterized by the rotting of the outer or cortical tissues of the lower part of the stem at or near the base. The rotting usually occurs below ground, but it may show at the surface of the soil or a little above. Plants which are attacked are checked in the early stages of growth, the leaves gradually become paler, roll upward, and ultimately die, the lower ones first. Examination shows that as a rule the seed tuber has rotted, and it is a reasonable presumption in such case that the rot started in this and spread thence to the stem base. The resulting crop of tubers may later be involved in a soft rot. Appel has shown this trouble in Europe to be due to bacteria (*Bacillus phytophthorus* Appel), and Morse (1909) and Smith (1910, pp. 748–749) have confirmed his conclusions as applicable to this disease in the eastern United States. Harrison (1906, p. 34) has described what may be the same disease in Canada as of a bacterial nature.

Potato stem-blight or rosette.—A disease having symptoms similar in some respects to black-leg has been described by Selby (1903) as rosette. It occurs in Ohio, in Colorado (Rolfs, 1904), and in several Central and Southern States. The cause is considered by these writers to be the fungus Rhizoctonia (*Corticium vagum* B. and C. var. *solani* Burt.). It is characterized by brown lesions on the underground portion of the stem and the stolons. The effect on the plant varies with the location and extent of these lesions from a dwarfed or rosette appearance of the leaves (Ohio) to a stimulation of foliage development due to prevention of tuber formation by cutting off the stolons (Colorado). The formation of numerous aerial tubers accompanies one type of this disease. This disease evidently is very similar to the black-leg type and there may have been some confusion of the two.

Potato wilt and dry end-rot.—Another widespread disease apparently most destructive south and westward in the warmer potato sections has been carefully studied by Smith and Swingle (1904), who concluded that it is caused by the fungus *Fusarium oxysporum.* The best marked symptoms are the falling or lopping over of stems and the wilting or curling of the foliage as a result of the killing of the smaller roots by this fungus. The tubers are later invaded and develop, especially in storage, a blackening of the vascular ring near the stem end. The further development of the fungus in the storage bin may lead to dry-rot, especially at the stem end of the tubers, and in advanced stages the fungus may appear as white tufts of mold on the surface.

Other leaf-curl diseases.—A form of disease characterized by leaf curling without the rapid wilting typical of the disease described by

Smith and Swingle is widespread in Europe (Blattrollkrankheit) and is probably an important factor in this country also. The causal relation of Fusarium to this disease is denied by many investigators, who believe it is partly or wholly physiological. Another type of leaf-curl malady known in Europe (Kräuselkrankheit) is occasionally seen in America. When attacked by this disease the foliage retains its normal color, but the stem, branches, and leaf veins elongate less than normal. A down curling and crinkling of the leaves results, with a denser bushy appearance of the plant as a whole. In mild cases the plant may later become normal. There is no reason to regard this as a parasitic malady. It appears to be an abnormal type of development which is, however, in its extreme form an inheritable characteristic and hence to be checked by seed selection.

Potato scab.—In all of the older potato-growing sections of America a scabbing of the tubers is common. Often deep pittings are shown, and it may even cause some cracking and may favor wet-rotting in heavy soils. In its commonest form at least this malady is due to a fungus (*Oospora scabies* Thaxter). Other forms of tuber scabbing occur, however, including the superficial black scurf caused by the fungus Rhizoctonia (Corticium) and the warty outgrowths known as the wart disease. It is probable that further study will show that still other types of scab occur.

Wart disease.—The European disease caused by the fungus *Chrysophlyctis endobiotica* Schilb. has recently been found in Newfoundland (Güssow, 1909) and is liable to be introduced elsewhere (Orton and Field, 1910). It is characterized by the appearance of warty outgrowths of the tubers which may ultimately transform the entire tuber into an irregular, deformed, black mass.

Internal brown-spot.—In the malady known as internal brown-spot the tubers outwardly appear normal, but when cut open rusty brown spots of varying size are found scattered irregularly through the flesh. These browned tissues are dead, but in typical cases are sterile, i. e., free from fungous or bacterial invasion. It is evidently a non-parasitic disease and, moreover, is not transmitted by the use of spotted seed. Probably it is due to malnutrition (Jones, 1905, p. 12).

Other causes for soft-rot.—The bacteria which cause the brown-rot and the black-leg diseases are both capable of causing soft-rot of the tubers. Soft-rot of tubers in storage or shipment from California has also been shown by Orton (1909, p. 916) to be due to a black mold (Rhizopus). If potato tubers are weakened or killed by any cause such as frost or bruising, especially if immature, and then held in storage, soft-rot may follow. Various organisms may be associated with such decay either functioning as pure saprophytes or else gaining such headway in the dead tissues that they pass on to the living tissues as facultative parasites.

EARLY OBSERVATIONS OF THE POTATO DISEASE AND ITS CAUSE.

EARLY HISTORY OF THE DISEASE.

The potato was evidently cultivated by the native people of certain parts of the American continent from prehistoric times. The earliest European explorers found it in cultivation in the temperate regions of the Andes Mountains with the appearance of having been a long-continued practice. Tubers were carried, probably from Peru or Chile, to Europe in the sixteenth century. There is some doubt as to the exact dates and places of the early importations, but the following statements, founded largely upon Roze's account (1898, pp. 61–85), are at least approximately correct. The first mention of the potato is in 1550 in a Spanish history of Peru, where it is noted that the natives near Quito cultivated it. The first clearly recorded European introduction is that into England in 1586 by Virginian colonists under the patronage of Sir Walter Raleigh, and the first account of the cultivation of the potato in Europe is by Gerarde, dating probably from the following year. There is, however, evidence that the potato was also introduced by the Spaniards into Spain, possibly at a somewhat earlier date. Roze believes this may have occurred as early as 1533. From Spain it was carried to Italy, Austria, Germany, Switzerland, and France. The first figures and detailed description of it in its new home in continental Europe are those of Clusius in 1601 in his Rariorum Plantarum Historia, although Gaspard Bauhin in his Phytopinax, printed in Basel in 1596, described it and gave it the scientific name it still bears, *Solanum tuberosum*. During the seventeenth century the potato gradually became, from a botanical curiosity cultivated only by collectors of new plants, one of the staple garden and field crops. By the latter half of the eighteenth century it was extensively cultivated and recognized as one of the regular crops throughout the temperate regions of Europe and America, so that Henry Phillips (1822, p. 78), who published in London in 1822 a detailed account of the potato and its culture, was able to cite a single grower who planted 300 acres annually. Indeed, it furnished the principal food supply of large parts of Ireland at that time.

These historical data with reference to the introduction and culture of the potato are cited in order to point out the peculiar significance of the fact that previous to 1830 there is no reference to any potato disease in Europe clearly referable to that caused by the fungus under consideration. Some time between that date and 1845 the disease appeared almost simultaneously in Europe and North America. The exact date of this initial appearance is about as uncertain as is that of the introduction of the potato itself. Some botanists, indeed, even go so far as to advance the idea that the disease was introduced along with the potato, and thereafter was continuously present in Europe but never became general in its spread. This view seems hardly worthy of consideration, however, since it is scarcely conceivable that so destructive a disease should have long escaped definite record. The known facts all indicate rather that it was first introduced into Europe during the years 1830–1840. There can be no doubt as to the early presence of the disease in South America. De Bary (1861, p. 63), quoting from Münter's Krankheiten der Kartoffeln, says that as early as 1571 the Jesuit Joseph Acosta had observed that after damp cold weather the tubers were often destroyed in the ground "through gangrene or mildew," and Boussingault on November 17, 1845, communicated to the French Academy of Sciences a writing by Acosta in which he stated that on the high table-lands of Bogota the potatoes on low ground were everywhere destroyed in wet years.

The details as to its introduction and subsequent spread in Europe constitute one of the most interesting chapters in the history of plant pathology. We are indebted to the critical accounts of Jensen (1887), Prunet (1902), and Roze (1898, pp. 290–322) for most that follows, especially as to the spread of the malady through Europe.[1]

Hallier (1868, p. 307) cites some evidence that it may have occurred in southern Germany and invaded the Rhine Valley between 1830 and 1840. In 1842 Von Martius published an illustrated account of it as a new disease of the potato then popularly known as Stockfäule (stem-rot) and Knollenfäule (tuber-rot). Von Martius made the first scientific study of the disease and published the first description and figures, although De Bary (1861, p. 7) erroneously gives credit for the figures to Mme. Lebert, who described it in 1845 in a periodical, "Organ des Flanders." Von Martius gave it the scientific name *Gangraena tuberum solani.* He communicated his results to the Paris Academy of Sciences and called the attention of governments and agriculturists to the gravity of the disease, but no precautions were taken. In 1844 the disease was general throughout Germany.

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[1] As already explained it was soon proved that this disease was due to the fungus *Phytophthora infestans,* which is native upon the wild potato of the Andean regions. It seems reasonable to conclude from the evidence that the outbreak of 1840–1844 followed within a few years the importation of the fungus from its native country to Europe and America. The question naturally arises as to why the disease was not transported in the earlier shipments of potatoes from South America to these countries. Evidence, to be cited later, shows that it may be carried in the tubers used for seed purposes. Jensen (1887, pp. 154–156) offers the following interesting and plausible theory:

He had already found (1887, p. 84) that the mycelium in the tubers was killed at a temperature of 25° C. The elevated Andean plateaus, where both potato and fungus are native, have so temperate a climate that this thermal death temperature is not reached. Any potato tubers carried thence to Europe in the early sailing vessels must, however, have endured long exposure to a higher temperature while passing through the tropical seas. Thus, Jensen concludes that during the first three centuries of potato culture, when the fungus was unknown in North America or Europe, the potato tubers were being disinfected by heat in the old sailing vessels while en route. After the invention of the steamship, the time spent in crossing the Tropics was much diminished. The date when those vessels came into general use, the decade 1830 to 1840, corresponds to the date of the earliest recorded occurrence of the fungus in the northern countries. These steamers could get out of the region of the Tropics in eight or nine days with large shipments of potatoes. It would take some time for the large bulk of potatoes in the hold of the vessel to be penetrated to the center by a temperature of 25° C.; and if in addition ice was used, as is common in vessels crossing the Tropics, there is no reason why the fungus might not be carried through the hot belt in this way.

In France Von Martius claims the disease already existed in 1840, according to the "Echo du Monde Savante." In 1841 it was so destructive in the Pfalz, Germany, that it attracted the attention of the Royal Scientific Academy at Munich, which engaged him to study the cause of the trouble. In Belgium the disease was first noticed in 1842 in the province of Liege, and to Charles Morren (Roze, pp. 298–299), the director of the School of Agriculture, is due the first recommendation, in 1845, to use the salts of copper in combating the disease. He urged that the fields be limed with a compound consisting of 25 parts of lime, 3 of table salt, 1 of copper sulphate, and 125 of water. He says:

> This mixture is prepared in a barrel and sprayed on the surface of the ground. One ought to use this mixture for liming the potatoes even when it is somewhat troublesome. A mixture of the same composition without water should be used for disinfecting the soil. The rain will spread it in the ground and cause it to act on the germs of the disease. This liming has for its aim the complete destruction of the germs of the fungus, just as a similar liming destroys the stinking smut of wheat, the smut of oats, or the ergot of rye.

Morren's mixture is essentially Bordeaux mixture with an excess of lime. Had he conceived its use as a foliage spray instead of merely for soil treatment, this standard fungicide might have been perfected much earlier.

In Denmark the disease already existed in 1842, according to M. Fjeldstrup (1844), and by 1844 had become so prevalent that meetings were being held to discuss the calamity. In Norway the disease was known in 1841 to Westrem (1851), the director of the School of Agriculture of that country. In Ireland Cooke (1892) states that it was present in 1842 and in England in 1845, although he says in his book, "Rust, Mildew, & Mould" (2d ed., p. 145): "In all probability this potato disease was present in less striking form one or two years before it took such an alarming spread." In England the development of the disease, as recorded in the Gardeners' Chronicle, seemed to proceed from south to north in 1845, the first year when it was general and serious. The Danish journals of the same year note its appearance in Holland, then successively in the north of Germany, and finally in Denmark, showing that a similar south to north advance occurred in continental Europe. Some have inferred from this that the fungus was first introduced into the south of Europe. Jensen (1887) points out, however, that this is the regular sequence of development which occurs annually because of climatic conditions. Plowright (1884) shows a similar condition to obtain in the British Isles. He collated reports of its appearance at the end of the month of July for the years 1877–1883, with the result that out of 100 reports from each of four sections 11 reported the disease from Scotland, 25 from the northern counties of England, 56 from the middle counties of England, and 89 from the southern counties of England.

In North America the evidence seems conclusive that the disease first appeared at about the same years as in Europe. B. M. Watson, of Boston, informed Jensen (1887, p. 151) in a letter that the disease occurred around that city in 1842; in 1843 it appeared around the city of New York (Prunet, 1902, p. 664), and in 1844 it was noted in many points in this country and Canada. In 1845 Andrew Bush, a doctor from Chester County, Pa., was awarded a prize of $20 by the New York Agricultural Society for the best essay on the rot of potatoes, at that time the disease having been present in different parts of the State of New York for at least two years. Bush's essay is worthy of more than mere mention, since his ideas were undoubtedly those of the most progressive American farmers of that time. The particular phase of the disease that impressed itself on him was the so-called "wet-rot," of whose stages he gives very careful descriptions. Apparently he did not clearly associate the blighting of the leaves with the rotting condition of the tubers, since he attributes this rot to "an epidemic condition of the atmosphere, brought into active influence by heat and moisture and producing the rot in the more tender varieties of the potato, or those raised from seed or badly cultivated, or under any circumstances unfavorable to their growth or preservation." His recommendations are to (1) plant sound potatoes from regions where the disease has not appeared; (2) give them plenty of nutrition in the form of lime, soda, potash, etc.; (3) intermix, in planting, potatoes of the same or different varieties cultivated in different soil or climate, to give the plant germinal stimulus; (4) plant whole potatoes in order to produce vigorous shoots; (5) mature the potato within 120 days of planting, i. e., plant early varieties; (6) take the potatoes up as soon as possible and store them in a cool, dry place. From this it will be seen that, while Dr. Bush had not apprehended the real cause of the disease as clearly as had Von Martius in Europe, nevertheless, his recommendations for field practice in combating it were most excellent.

The year 1845 marked the culmination of the epidemic. It swept through Europe and North America, devastating the potato fields, frequently leaving famine in its wake. In America it was most felt in Nova Scotia and New Brunswick (Farlow, 1875), where the potato was the leading crop. In Europe none of the potato-growing sections were exempt, but the loss was most disastrous in Ireland. In 1845 over 4 per cent of all the land of Ireland was planted with potatoes and a majority of the 8,000,000 people were dependent upon them for food. There never were enough potatoes planted to last during the entire year—at best three months—June, July, and August being "meal months." When practically the entire potato crop failed, the suffering was intense. Every form of government and private aid was extended, but in spite of this about a quarter of a million people died of famine or from the fever resulting from lack of food. Since 1845 the disease has occurred in all the potato-growing countries of the world, although no subsequent epidemic has equaled that one.

EARLY INVESTIGATIONS OF THE CAUSE OF THE DISEASE.

When the disease became epidemic in 1842–1845 little exact knowledge was available concerning the relation of parasitic fungi to plant diseases. The stimulus to intensive study of plant pathology occasioned by this outbreak was enormous. Norton (1846, p. 350), writing from Edinburgh, Scotland, in 1845, says:

> To the poor (in these European countries) the potato may be considered the staff of life. In many parts thousands of families rarely obtain any other food from one year's end to another. The disease became a natural calamity. The fear of famine became universal, and every energy is aroused to avert the danger. Something must be done or the potato bids fair to become extinct. Scientific men in various countries have accordingly turned their attention to it and in most cases have been aided either by their respective governments or by agricultural societies. Among the first on the continent was a commission from Holland and Belgium. In Germany, Liebig, among others, has turned his attention to the subject. M. Payen has lately published three or four reports containing the results of elaborate microscopical and chemical researches. Bouissingault, A. Peroz, and others have also made public their opinions. In Britain and Ireland a great portion of the best scientific and practical men are now uniting their efforts. The English Government has sent to Ireland three competent chemists, with Dr. Lindlay as botanist and physiologist.

At first there was the most extreme difference of opinion as to the cause of the disease. Again quoting from Norton (p. 367) as well reflecting this state of affairs:

> Some ascribe the disease to electricity, some to atmospheric influence, some to wet season, some to wet, drought, and frost combined, some to insects or animalculæ, some to ruptures of the cell, some to decomposition of proteins.[1] others to fungi, others to a diseased and vitiated constitution in the potato weakened by long and high cultivation, others unite nearly all of the above, others still ascribe it to a direct visitation of Providence, and yet another class declare that they know nothing about it. I think these last are the safest at present.

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[1] This view was held by the German chemist Liebig.

Of course, such a battery of investigations soon disclosed the fact that a fungus was associated with the disease, but the majority at first were of the opinion that this was a result or sequence of the diseased state rather than the active cause. So far as we can learn, the first scientific writer to ascribe the disease to a parasitic fungus was Von Martius (1845), whose figures of the fungus, while crude, are easily recognizable. In 1845 Morren affirmed the same idea and adduced in its favor experimental evidence based on inoculations. Moreover, Morren based his field treatment, already outlined (p. 21), on the assumption that the spores of the fungus carried the disease from plant to plant. The fungus was described by Montagne, September 3, 1845, under the name *Botrytis infestans.*

The discovery and description of the fungus were only one step, however, in the settlement of the controversy as to its causal relation. Opposed throughout to Von Martius and Morren were all the ignorance and superstition of the time, backed by such authorities as Schacht, Descaisne, and Berkeley (Prunet, 1902, p. 99). The opinion held by men like Schacht was that the fungus was only a saprophyte following closely some physiological disturbances in the leaf and probably aggravating the trouble. The opposition to the idea of the parasitism of the fungus was too great, and for a decade after the discovery of the Phytophthora it was generally regarded as incidental to the disease, not its efficient cause, and Von Martius and Morren were discredited.

Speerschneider (1857) was able to demonstrate for the first time that the spores borne on the leaves are capable of carrying the disease from them to the tubers, but as Von Holle (1858), who repeated his work the following year, was unable to get the same results the question remained unsettled. It was left for De Bary (1861, 1863) to complete the demonstration; his masterly work, which will be reviewed later, has left no doubt as to the parasitism of the fungus and its causal relation to the disease.

NOMENCLATURE AND OCCURRENCE ON OTHER HOSTS.

There was naturally some confusion concerning the nomenclature of the fungus in connection with these earlier studies. This, together with the facts as to its occurrence on other host plants, was determined by the studies of De Bary and others later. It will simplify the method of presentation, however, to summarize here the facts as to both of these matters.

The scientific naming of the fungus associated with the disease (Prunet, 1902, p. 98) is as follows:

1842. Von Martius, *Gangraena tuberum solani.*[1]
1845. Montagne, *Botrytis infestans.*[2]
1845. Lebert, *Botrytis devastatrix.*[3]
1845. Desmaxieres, *Botrytis fallax.*[4]
1846. Hartig, *Botrytis solani.*[5]
1847. Unger, *Peronospora trifurcata.*[6]
1852. Caspary, *Peronospora fintelmanni.*[7]
1855. Caspary, *Peronospora devastatrix.*[8]
1863. De Bary, *Peronospora infestans.*[9]
1876. De Bary, *Phytophthora infestans.*[10]

The scientific name for the fungus as written is accordingly *Phytophthora infestans* (Mont.) De Bary. De Bary at first followed Unger (1847) in placing the fungus in the genus Peronospora, but in connection with his special study of it for the British Agricultural Society (1875) he created the new genus Phytophthora on account of the peculiar mode of production of the conidia; several conidia, instead of one, being successively formed at the end of each branch of the treelike conidiophore, each conidium leaving behind it a swelling on the branch. No other species of similar character was then known, but six species have since been added (Wilson, 1907, pp. 387–393; Klebahn, 1909; and Coleman, 1910, pp. 620–621). The species of Phytophthora now known are as follows:

Phytophthora cactorum (Cohn and Lebert) Schröter. (*P. omnivora,* De Bary). This fungus attacks seedlings and the soft tissues of mature plants ranging through 15 families from the Pinaceæ to the Scrophulariaceæ, and of wide geographical range. A variety of this species (var. *arecae* Coleman) is a parasitic on the areca palm.

Phytophthora colocasiae Racib., a tropical fungus occurring on the taro (*Colocasia antiquorum*).

Phytophthora nicotianae Van Breda de Haan, a tobacco pest in the East Indies.

Phytophthora phaseoli Thaxter, occasionally occurring on the Lima bean (*Phaseolus lunatus*) in the eastern United States.

Phytophthora thalictri Wilson and Davis, recently discovered by Davis in Wisconsin on *Thalictrum purpurascens.*

Phytophthora syringae Klebahn, related to *P. cactorum;* occurs on lilacs, especially when stored for forcing.

Phytophthora theobromae Coleman, parasitic on *Theobroma cacao* and other plants.

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[1] Die Kartoffel-Epidemie der letzen Jahre oder die Stockfäule und Räude der Kartoffeln, Munich, 1842.

[2] L'Institut, no. 609, 1845. Société Philomathique de Paris, August, 1845.

[3] Revue Botanique de Duchatre, vol. 1, p. 151. Journal de Liege, August 19, 1845.

[4] Cryptogames de France, 1st ed., p. 492.

[5] Annales des Sciences Naturelles, Botanique, ser. 3, vol. 6, 1846.

[6] Botanische Zeitung, 1847, p. 314.

[7] Verhandlungen des Verein zur Beförderung des Gartenbaues in den königlich preussischen Staaten, 1852, p. 327.

[8] Monatsberichte der Berliner Akademie der Wissenschaften, May, 1855.

[9] Annales des Sciences Naturelles, Botanique, ser. 4, vol. 20, 1863, p. 104.

[10] Journal of Botany, 1876, p. 105.

It is also to be noted that the potato is not the only host of *Phytophthora infestans.* De Bary (1876, pp. 126, 149) mentions that it has as hosts not only a number of other species of the Solanaceæ grown in gardens, but that he has observed it on one of the exotic species of the Scrophulariaceæ, *Schizanthus grahami*, and that Berkeley has described a case where it occurred on another one of the same group, *Anthocercis viscosa*, from New Holland. It frequently happens that it becomes as destructive to the tomato as to the potato, and the first attempt in using the Bordeaux mixture against it was by Jouet (Prunet, 1902, p. 356) on the tomato. De Lagerheim (Prunet, 1902, p. 269) has found it on the edible fruits of *Solanum muricatum* at the equator, on *Solanum caripease* at Quito, and on *Petunia hybrida* at Upsala.

LATER STUDIES OF THE FUNGUS AND REMEDIAL MEASURES.

RELATIONS OF THE PARASITE TO THE HOST PLANT.

CAUSE OF THE DISEASE.

It has already been explained how it remained for De Bary (1863, pp. 59–68) fully to establish the fact that inoculation of healthy potato leaves with the spores from diseased leaves would lead to the same malady in them. It is to him, in this same publication, that we owe our first accurate knowledge of the relation of the parasite to its host plant. He found that by sowing the Phytophthora spores on the unaffected leaves the germ tubes would penetrate the epidermis, develop the mycelium intercellularly in the parenchyma, and cause the diseased spots. The manner in which the spot increased centrifugally and the transfer of the disease to the stalk and tubers were also noted by him.

The following account by De Bary (1863, pp. 46–47) will give a clear idea of his understanding of the development of the parasite and its infection of the potato:

> On the 9th of February, at 5 o'clock in the evening, the conidia were sown in drops of water on glass slides. They were then put on stems cut from the potato and placed in a damp chamber. At 7.15 the zoospores were fully developed and had pushed out a germ tube. On the morning of February 10 it was found that these germ tubes had penetrated into the potato tissue; on the 11th of February the mycelium had expanded freely in the intercellular spaces of the parenchyma, being found to a depth of six cell layers. February 14 the mycelium had gone through the whole parenchyma and numerous conidiophores were coming upon the surface of the stems. Many trials seemed to give the same results. I will cite two: Sporangia sown at noon produced zoospores at 1 o'clock. At 3 o'clock the germ tubes could already be seen buried in the wall of the host cells. February 4 conidia were sown on potato leaves; the fifth, the germ tubes had penetrated; the eighth, one of the infected leaves showed conidia; the ninth, the conidiophores appeared on the other leaves.

MICROSCOPIC STRUCTURE OF THE PARASITE.

In order to make a closer examination of the fungus it is necessary to cut thin sections from a diseased leaf and examine them under the compound microscope. It will then be seen that the nonseptate mycelial threads of the parasite occupy the intercellular spaces of the potato leaf and that through the stomata issue slender branches, the conidiophores, bearing ovoid conidia at the ends or occasionally on the sides of their smaller branches (figs. 3 and 5). It is noticeable that the walls of these conidiophores, probably in order to give them necessary stiffness, are much thicker than those of the hyphæ in the leaf and frequently have cross walls and that the side branches are swollen at places marking the points where conidia have been borne. The mycelium shows the structure common to the fungi of this group—large, nonseptate, thin-walled hyphæ, containing many nuclei (Pl. VIII, fig. 48). The conidia are borne on the aerial branches, most abundantly on the under side of the leaf; in shape they are ovoid with a short stalk and an apiculate tip (figs. 3 and 6). They are multinucleated as soon as formed and when mature contain 7 to 30 nuclei (Pl. VIII, fig. 49). The germination of this conidium may take place in either of two ways: (1) Directly, i. e., by pushing a single germ tube usually through the apiculate apex (fig. 6), or (2) indirectly, i. e., by splitting up into a variable number of biciliate zoospores (fig. 7), which, after swimming about for a short time, lose motility, withdraw the cilia, form a wall, and push out a germ tube.

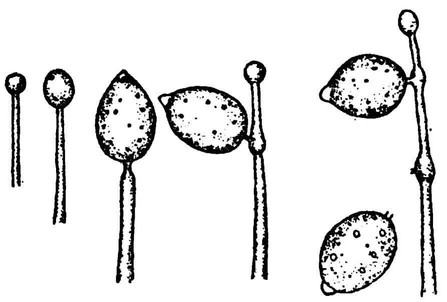

FIG. 5.—Sketch showing the successive stages in the development and abstriction of the conidia of *Phytophthora infestans*. (After Ward.)

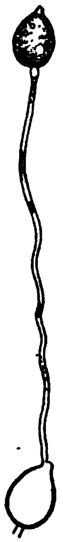

FIG. 6.—Sketch showing the direct germination of a conidium of *Phytophthora infestans* by tube formation. (After Ward.)

It was shown by De Bary (1863, pp. 42–43) that environmental conditions may determine which of these two methods of germination is followed. He was unable to determine the exact conditions for producing one or the other type, since direct germination occurred occasionally even where zoospore formation predominated. He reached the conclusion, however, that light hindered the production of zoospores. The production of zoospores occurred in conidia when they were sown on cut potato tubers, but he found (1863, p. 41) that the other method of direct germination is the more common one in this case, although he also frequently obtained the normal production of zoospores.

This is in accord with the experience of the writers in finding that sowing the conidia in potato juice favors direct germination. It is also found that temperature affects the process. At 25° C. more than 50 per cent of the germinations are by tubes, while at 10° to 20° C. from 60 to 70 per cent produce zoospores and direct germination is exceptional. De Bary states (1876, p. 240) that each sporangium produces 3 to 8 zoospores. Although we have not made counts during germination we have found that there are more than this; indeed, De Bary's figures (1876, p. 242) would so indicate. As evidence upon this point our staining shows the conidia to have from 5 to 30 nuclei. Since the swarm spores are uninucleate they must equal this number.

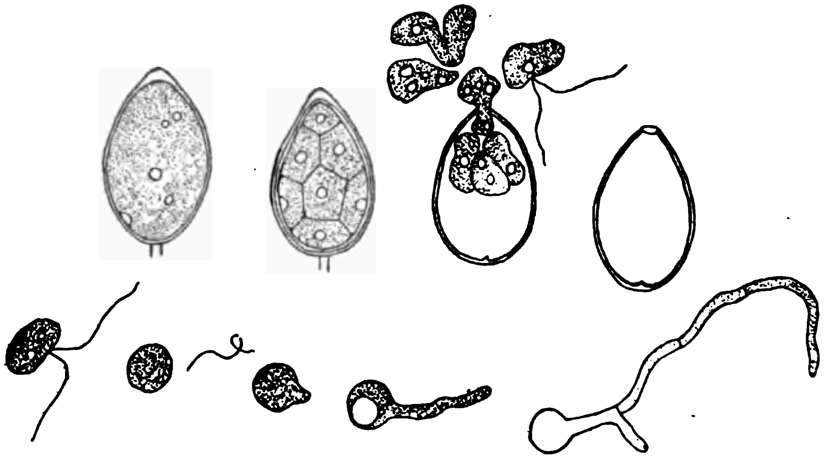

FIG. 7.—Sketch showing the indirect germination of *Phytophthora infestans* by zoospore formation. (After Ward.)

While the conidia are always figured as being borne on conidiophores outside the leaf we have found that they may also be borne internally in the mesophyll. Usually these internal conidia occur singly as short side branches at any point on the mycelium, but more commonly on the hyphæ which traverse the air chambers below the stomata. These internal sporangia were apparently of the same type as the aerial ones. Their occurrence within the tissue of the leaf is of interest and of possible significance as bearing upon the nature of the resting spores discussed later in this bulletin.

The related Peronosporales typically produce sexual resting spores, oospores, and De Bary and others have searched persistently for such spores in potato leaves and tubers and in other host plants invaded by *Phytophthora infestans*. It must suffice at this point to record that, although some, notably Smith (1875, 1876) and Smorawsky (1890), have stated that they found them, the evidence they presented to substantiate their claim has not been accepted as conclusive. Since our own investigations bearing on this point have been conducted almost entirely through the use of pure cultures the results will be discussed later in connection with them.

RELATION OF THE FUNGUS TO THE HOST TISSUES.

A careful examination of the relation of the fungous hyphæ to the host cells of the leaf will show that, as De Bary (1876, p. 275) noted, they press against the walls so closely that these are occasionally pushed in and sometimes penetrated. These finer structures can be best studied in properly fixed and stained sections. It will be seen then that, as Mangin (1895) has already described, this penetration of the host parenchyma cells is not a rare occurrence, as De Bary thought it to be, but that it is very frequent, particularly in the lower epidermal cells. The overshadowing effect of De Bary's work has led subsequent mycologists in general to assume that since he was unable to discover any true haustoria in the leaves there are none. It must be remembered, however, that he depended entirely upon free-hand, unstained razor sections, whereas, properly stained microtome sections will confirm the statement of Mangin (1895) that many of the parenchyma cells are penetrated by slender branches, which undoubtedly serve as haustoria. The appearance of such branches constitutes good presumptive evidence that they function actively as special absorbing organs, and this idea is further supported by the rapid collapse and death of the potato parenchyma following the fungous attack.

Very little can be made out of the relation of the haustorium to the potato cell, on account of its small size, but, as happens in many other species, such as the Erysiphaceæ, the host cell wall is extended down so as partly to inclose the parasitic branches. The fungus apparently soon dies in the black portion of the spot where the host cells are all dead, unless it be kept moist, but it continues to grow and to fruit on those that have the chromatophores largely disorganized. This ability to live in a partly saprophytic stage, while probably of limited duration in the normal course of development of the fungus, is probably the same that enables it to grow on the various culture media to be described later. The condition of the host cells is also interesting at this time. The fungus does not disorganize the chlorophyll bodies at once, but cells that are completely surrounded by the fungous mycelium still show chloroplasts full of starch grains. It is not certain as to just the meaning of this, which is a not infrequent result of fungous parasitism. The leaf cells may be able to continue the manufacture of starch even in the presence of the parasite, or it may be that the attack is so sudden that the cell is caught with its chloroplasts full of starch and is unable to secrete the necessary diastase to translocate it.

The relation of the fungus to the cells of the potato tuber was also given some attention by De Bary (1876, p. 250), who found that the mycelium here, as in the leaf, lay largely between the cells, but that small branches, which he called suckers, were pushed into their interior. Delacroix (1903, pp. 360–362) in later years described what he considered true haustoria in the infected tissue of the potato tuber. When we had perfected the methods of handling the fungus in pure cultures on potato blocks, as described on a later page, attention was turned to this question. The Delacroix material, of which he courteously gave us a slide for examination, was taken from naturally infected, decaying tubers. For our studies thin slices were cut and sectioned from potato blocks on which the fungus was growing in pure culture. The sections were cut from the blocks at right angles to the surface, immersed in a 5 per cent solution of caustic potash to clear the starch, rinsed in water, further clarified by immersion in eau de Javelle, again rinsed, and then stained for a short time in a 1 per cent lactic-acid solution of cotton blue, as advised by Delacroix.[1]

If properly manipulated this solution gives a faint differential stain to the mycelium. Our examination fully confirms Delacroix's statement as to the occurrence of the haustoriumlike branches penetrating the tuber cells (Pl. VIII, fig. 53). It seems a reasonable inference that these haustoria contribute to the disorganization of the protoplast both by the action of toxic or enzymic secretion and by the ultimate absorption of some part of the cellular contents. The actual rotting of the tuber is due, however, as Delacroix (1903, pp. 365–373) has shown, to other fungi and particularly to the bacteria which follow the Phytophthora closely and cause the soft-rot that develops in wet soils. This is, perhaps, most convincingly shown where the fungus is grown in pure culture on sterile raw-potato tissues in the method explained later in this bulletin. Such potato tissue is never softened.

MODE OF TUBER INFECTION.

The mode of infection of the tubers in the soil is a phase of the disease that was carefully studied first by De Bary and later by

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[1] The details of the method are that after clearing the starch by the potash solution and rinsing in water they were allowed to remain in eau de Javelle 10 minutes. They were then transferred, after washing in water, to a staining solution made up as follows: 1 c. c. of a saturated aqueous solution of cotton blue was added to 9 c. c. of water, then 3 or 4 drops of this diluted solution were transferred to 10 c. c. of a 1 per cent solution of lactic acid, in which the sections were allowed to remain overnight. The sections were then washed in water and mounted in glycerin.

Jensen (1887). De Bary showed that such tuber infection does not occur, as might naturally be expected, by the downward growth of the mycelium from infected leaves through the stem to the tuber. He satisfied himself that it came instead from the spores falling or being washed from the leaves into the soil. Appreciating the bearing of this method of infection upon possible remedial measures, Jensen (1887) conducted painstaking experiments to determine the relation of soil texture and depth to such infection of tubers. He states that when spores in water were poured upon a soil filter he found that less than 1 per cent of them were able to penetrate to a depth of 5.2 cm. (2 inches) and that none of them, or at most very few, were able to penetrate to a depth of 13 cm. (5 inches). Moreover, light, sandy soils held the spores much better than heavy clay.

The following experiment, recently made, gives evidence of the correctness of Jensen's general conclusion, although it shows that he relied too much on his soil filtration. Two similar trenches were dug, side by side, in a sandy garden soil. Each trench was 40 inches long by 15 inches wide and of depths varying from 4 inches at one end to 10 inches at the other. Each trench was then divided into three equal parts by upright boards set crosswise and 23 healthy Green Mountain potato tubers were buried in each compartment. In one trench (A) clay soil was used for burying the tubers and in the other (B) a light, sandy soil. In each trench the upper surfaces of the tubers were covered to a depth of one-half inch in the shallow compartment, of 3 inches in the middle compartment, and of 6 inches in the deepest compartment. Branches cut from blighting potato plants, with an abundance of Phytophthora in fruit, were then laid upon the surface of each trench and sufficient water sprayed on them to wet down the soil thoroughly. A piece of sacking was then placed over the soil and, as the weather was dry, the soil was again sprayed on each of the two succeeding days to insure an abundance of moisture such as is most favorable under natural conditions for the development of the rot. At the end of 15 days the trenches were opened and the tubers compared as to infection by the fungus, with results as shown in Table I.

TABLE I.—*Experiment showing comparative Phytophthora infection of potato tubers through varying depths of clay and sand.*

Depth of covering.	Tubers infected.			
	Trench A, clay.		Trench B, sand.	
	Number.	Per cent.	Number.	Per cent.
One-half inch (1.25 centimeters)	23	100	13	57
Three inches (7.5 centimeters)	22	96	11	48
Six inches (15 centimeters)	14	61	7	30

JENSEN'S REMEDIAL MEASURES.

Deep burying of the tubers.—As a result of his experiments Jensen devised a method of culture designed to protect the tubers from primary infection by deep burying during late summer. This he was able to do by heaping up the soil in ridges with steeply sloping sides until the vines were partly covered and the tubers were buried to such a depth that there would be no danger that the zoospores could get through the overlying soil. Assuming that the potato rows were 78 cm. (31 inches) apart, he recommends an addition of a layer of 10 to 12 cm. (4 to 5 inches) in thickness above the tubers, although, he says, a layer of 7 to 8 cm. (2½ to 3 inches) suffices in light soil, making a hill 28 to 30 cm. (11 to 12 inches) high from the bottom of the furrow. It is recommended that this be done about 10 days before flowering. In this manner the tubers could be kept sound, even though the vines were devastated by the fungus.

This method of banking up the rows very high, while successful in preventing the disease on small trial plats, was later proved to be impracticable, since it caused a considerable loss in yield. This is probably due, as pointed out by Peterman (Prunet, 1902, pp. 355–356), who tried the Jensen method at the agricultural station at Gembloux, to the strongly inclined sides of the rows shedding most of the water during rainfall and during dry weather increasing the evaporation by their slopes. In this way the tubers do not get sufficient water for their proper development and the yield is diminished. It is a method that can be successfully employed only in rainy seasons or in a very humid climate.

Tuber disinfection.—Jensen also conducted extensive experiments on the care and disinfection of tubers already invaded by the fungus, the results of which are of possible importance to the practical man as well as to the mycologist. These experiments were based largely on the facts he learned as to the thermal death point and the optimum conditions of temperature and moisture for the fungus. The death point for the spores was found to be about 25° C., while the mycelium in the tuber was all killed by an exposure of the tuber to a temperature of 30° C. for 65 hours, 35° C. for 16 hours, or 40° C. for 4 hours. The fungus, on the other hand, would not produce spores at or below a temperature of 5° C., moisture being required, of course.. As a result of these observations he recommended that tubers suspected of harboring the fungus be stored in dry cellars in which the temperature did not rise above 5° C., since this will suffice to hold the disease in check. For purposes of disinfection he further recommended that potatoes designed for use as seed be subjected to a temperature of 40° C. for 4 hours in a water-jacketed chamber. So long as the tubers are not in contact with the water, this temperature, although considered sufficient to insure the destruction of the fungus within the tubers, was found not to injure the germination of the potato itself. It would seem that so simple a method as this for seed disinfection would have found immediate favor in practice, especially in the potato-growing sections of Europe, which suffer so regularly from this disease. As a matter of fact, however, its use never passed the experimental stage so far as we can learn. The chief reason for this is probably because no one has demonstrated by field experiment that such disinfection pays. Trials, though on rather a small scale, made at the Vermont station failed to show any practical benefit, and this experience seems to have been general. The further explanation of this failure probably lies chiefly in the fact that unless such disinfection were to be practiced by all growers simultaneously over a large area it would do little good, since with favoring weather conditions the fungus would spread very rapidly over a wide territory from any untreated field remaining as a center of infection. Moreover, it often seems difficult to account for the sudden reappearances of the disease at remote points and after rather long intervals if it is wholly dependent upon the vegetative mycelium in the infected tubers for its perpetuation. The possibility, if not probability, of some form of resting spore has been recognized by every student of this disease from the time of Berkeley and De Bary.

STUDIES OF INFECTION AND DISSEMINATION MADE IN VERMONT.

PRACTICAL QUESTIONS INVOLVED.

Although Jensen's method for tuber disinfection has not come into practical use, the questions involved, especially as to time and method of tuber infection in the soil, the spread of that infection to other tubers either in the soil or in the storage cellar, and the production of infected plants from infected seed tubers, are all matters of so much economic importance that further investigations bearing upon them have been undertaken from time to time in connection with the Phytophthora studies at the Vermont station. The current ideas on the subject, based largely upon De Bary's work, are as follows: The conidia falling from the diseased leaves to the ground infect the tubers under them, producing a primary infection; from this primary infection the fungus may spread from one tuber to another, at least in the storage cellar; tubers may be quickly killed by the rot or they may be invaded by the fungus without showing evident external symptoms of the rot and, if such are planted the following season, the shoots coming from them may harbor the fungus, which will in due season sporulate, thus starting the infection of the second year.

In the work that has been done at this station in connection with the present studies, the attempt has been made to secure further evidence along these lines upon several matters of more or less practical importance.

1. When and how does the primary infection of the tubers occur in the field?
2. Does secondary infection of the tubers occur in the field before digging, i. e., may the fungus spread from tuber to tuber in the soil?
3. Are healthy tubers liable to infection from contact with blighting foliage at the time of digging?
4. When the blight appears on the foliage should the crop be harvested at once or should the digging of the tubers be delayed until the season of normal maturity?
5. May infection occur in storage, i. e., may the fungus fruit on mature tubers in storage and the spores infect other mature tubers?
6. If such infection does occur is it through the unbroken skin, the eyes, or the lenticels?
7. Do infected seed tubers give infected plants if used for seed?

PRIMARY INFECTION OF TUBERS IN THE FIELD.

De Bary, Jensen, and others concluded as a result of their studies that the tubers are infected, as a rule at least, by spores washed through the soil from the blighting foliage. It has been repeatedly observed when digging potatoes that tubers at or near the surface show more rot than those buried deeper in the soil and that the rot is more apt to begin on the upper side of the tuber. Examinations have shown that it appears nearly as often at the tip end of the tuber as at the stem end. All of these facts are in accord with the above idea that the infection passes from the foliage through the soil rather than by way of the stem. Moreover, experiments which will be summarized later were made at the outset of the work (Jones, 1891, 1893) which showed that by properly spraying the foliage the development of the fungus is checked and that when this is done little or no rot develops in the tubers. This also is in accord with the idea outlined above so far as it bears upon the question. In order to meet the conditions of the problem more directly, trials were made to learn what will be the result if the surface of the soil is sprayed while the foliage is unprotected and attacked by the fungus. This is, indeed, essentially what Morren (1845) recommended some 65 years ago as a means of checking the rot of the tubers. Opportunity was offered for trial of this method during two seasons, 1902 and 1905. In each case the blight was prevalent and all the foliage of the trial plats was attacked and destroyed.

In the first trial (Jones and Morse, 1902) the soil was sprayed twice, August 13 and September 6. The second trial (Jones and

Morse, 1905, p. 273) involved three sprayings, August 2, 18, and 28. The results are shown in Table II.

TABLE II.—*Comparative effect of spraying and nonspraying of soil for control of rot of potato tubers.*

Treatment of soil.	Percentage of rot.	
	Experiment 1.	Experiment 2.
Not sprayed	19	31
Sprayed	2	17

A marked reduction in the percentage of rot in the sprayed soil is shown for both seasons, this reduction being in accord with the idea that tuber infection occurs primarily through the soil. In neither case were the experimental conditions perfect. In the first experiment some development of the fungus on the foliage had occurred, and so also possibly some tuber infection, before spraying began. In the second experiment a heavy rainfall occurred in September when the fungus was rampant on the foliage, and the tubers were not dug until October 13. Doubtless one or more additional sprayings of the soil in September and early October would have further reduced the rot.

SECONDARY INFECTION OF TUBERS IN FIELD OR STORAGE.

The possible importance of secondary infection, i. e., the passage of the fungus from tuber to tuber in the field or storage bin, was emphasized by observations made in the autumn of 1905. When the crop growing in a moist, heavy soil was dug, considerable rot was found and a large number of the tubers which were in the early stages of decay had small white tufts of the Phytophthora (Jones and Morse, 1905, pp. 284–287) scattered over the surface and bearing abundant crops of spores capable of germination (Pl. III, fig. a). Moreover, in some places the mycelium was ramifying through the interstices of the soil at least one-half an inch from the surface of the decaying tuber, although doubtless nourished by it. All the tubers showing decay were sorted from the crop, which was then stored in shallow boxes in a dry cellar at 50° to 55° F. Later, in October, these boxes were reexamined and occasional tubers were again found bearing thrifty tufts of Phytophthora, rupturing the lenticels and sporulating abundantly (Pl. III, fig. b). It is evident, therefore, that the fungus may fruit freely enough on the tubers, either in field or storage, to supply spores for further tuber infection, providing mature tubers are susceptible.

Repeated trials have shown that sowings of the fungous spores on mature potato tubers at any time during their dormant period will lead to infection if sufficient moisture is present. The results of a

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single experiment are here given. Twenty-four healthy Green Mountain potatoes were selected in midwinter and arranged in groups of six. Conidia from a vigorous culture of Phytophthora were left in water until they began to germinate. A drop of this spore-laden water was then placed upon each tuber: In the first group in an eye of each tuber; in the second, upon a prominent lenticel; in the third, upon a spot slightly abraded so as to expose the flesh; and in the fourth, upon the unbroken skin where free from visible lenticels. Each point of infection was marked by an India-ink circle and the tubers were then stored in a moist chamber and kept at about 18° to 20° C. At the end of three weeks all of the tubers inoculated in abrasions showed infection. Two of those having spores applied to the eyes, two having spores on lenticels, and one having spores on the unbroken surface were infected. From this experiment it is clear that the mature tuber is not proof against infection even where no bruises or wounds occur, although freshly bruised or wounded tubers are more readily invaded.

INFECTION OF TUBERS AT TIME OF HARVEST.

The results outlined suffice to show the danger of infecting the tubers by harvesting the crop at a time when the partially blighted tops are heavily laden with spores. A trial made in 1905 (Jones and Morse, 1905, pp. 285, 286) bears still more directly upon this point. The freshly dug tubers from a blighting field were sorted into two piles; one was covered with a layer of the blighting tops, the second with sackcloth. Both piles were then sprinkled with water and allowed to remain overnight before putting them in the storage cellar. The result was that every tuber from the first lot decayed within eight weeks, while only 54 per cent of the second lot developed rot. Of course there had been abundant infection in the field preceding digging, but the infection from the blighting tops was so complete that it doubtless would have destroyed all of the tubers of the first lot had there been no field infection.

RELATION OF DATE OF DIGGING TO DEVELOPMENT OF ROT.

Several of these facts have a bearing upon the question of the relation of the date of digging to the development of the rot. The fact that the infection washes from blighting tops through soil to tuber argues for early digging when the disease is bad. Opposed to this is the fact that digging while the blighting tops are producing spores may expose the tubers still more generally to infection and that the disease may spread more rapidly in the freshly bruised immature tubers. Experiments were carried on during two seasons (Jones and Morse, 1902–3, 1903–4) which gave convincing evidence that under any except the most unfavorable soil conditions early digging is unwise. The average of the trials of two seasons (Jones and

Morse, 1903–4, pp. 391–395), including tests upon several different fields and varieties, was as shown in Table III.

TABLE III.—*Experiments showing relation of date of digging of potatoes to development of rot.*

Date of digging.	Sound potatoes dug.	Development of rot.	Date of digging.	Sound potatoes dug.	Development of rot.
1903.	*Pounds.*	*Per cent.*	1904.	*Pounds.*	*Per cent.*
Aug. 31	84	55.3	Aug. 22	403	4.3
Sept. 7	150	25.7	Aug. 29	440	11.8
Sept. 14	169	15.8	Sept. 5	510	18.4
Sept. 21	175	11.4	Sept. 12	599	8.9
Sept. 28	171	7.3	Sept. 19	578	8.0
			Sept. 26	618	6.0

The results of these experiments led to the formulation of the general rule that where the tops are attacked by the late-blight the harvesting of the tubers should be delayed until a week or more after the death of the tops and that longer delay does no harm, but in exceptionally wet seasons and on low, heavy soil, where the fungus develops rapidly on the tubers underground and so spreads in the hill, early digging is necessary, else the entire crop may be lost.

RELATION OF STORAGE CONDITIONS TO DEVELOPMENT OF ROT.

The relation of storage conditions to the development of rot has also received practical test in connection with these studies. While it has already been shown that the fungus may, under exceptionally favorable conditions, continue to fruit on the tubers in storage and so spread from tuber to tuber, our trials lead us to believe that if the cellar is properly dry and cool this will not occur to any serious degree. The use of lime and disinfection with formalin have proved to be valueless under such circumstances (Jones and Morse, 1905, pp. 280–281). On the other hand, the drying of tubers before storage (Jones and Morse, 1905, p. 282) and also the low temperature of the storage cellar, as advocated by Jensen, are important. Thus the apparently sound tubers from a field where the tops were killed by the late-blight were divided into three lots and stored at about 40°, 55°, and 70° F., respectively. The amount of rot at the end of two months was 17, 53, and 79 per cent, in the order named.

PROPAGATION FROM SEASON TO SEASON.

De Bary (1876, p. 267) followed the fungus from infected seed tubers into the stem and foliage of the shoot developing therefrom and observed the sporulation upon these aerial parts. There can be no doubt, therefore, as to the possibility of the fungus overwintering in this way, and it seems probable that this method is the common means of propagation from season to season. De Bary (1876, pp. 266–269) first experimentally tested this matter in the field by planting artificially inoculated tubers and found that while no sprouts would come from the eyes in or near the diseased areas they would come from others at some distance away, some of these latter ones being affected by Phytophthora. Jensen (1887, pp. 120–122) repeated the experiments in 1883 by planting diseased and healthy tubers in parallel rows, at the same time attempting to discover whether the diseased shoots would be able to reach the surface of the ground in case the diseased tubers were planted deep. Fifty diseased tubers were planted 10 centimeters deep and a like number 21 centimeters deep. From those at a depth of 10 centimeters 24 plants came up; of these 24 plants only 1 was very vigorous, 18 were unaffected by the disease, while the other 6 showed it as brownish spots on the stem near the ground. Of the 50 diseased tubers planted 21 centimeters deep only 19 came up, and 1 of these was diseased and soon died. From this experiment he concluded that the deeper planting made it impossible for the weakly, diseased shoots to pierce the thick layer of soil on top of them and that there must be a delicate balance among these three factors—the vigor of the shoot, the virulence of the Phytophthora, and the thickness of the layer of soil the shoot has to penetrate before reaching the light.

In our earlier experiments attempts were repeatedly made to get evidence bearing upon this overwintering of the fungus by planting tubers showing varying degrees of dry-rot which was started by natural infection with Phytophthora. In no case, however, has positive evidence been secured. Either there was no growth or else the sprouts appeared normal. So far as conclusions are justified by such negative results, it would seem that if the fungus successfully overwinters in the tubers it is in cases where its attack is very mild, i. e., where it remains so nearly dormant that it causes little or no dry-rot or other visible injury. In two later experiments artificial infection has been resorted to in order to learn the relation of the fungous invasion to the development of the shoots. On May 21, 40 healthy Green Mountain tubers of uniform appearance and with strong sprouts one-half inch to 3 inches long were chosen for the experiment. Twenty of these tubers were inoculated with bits of mycelium from pure cultures in slits cut near two or three of the healthy eyes in each tuber, these eyes being marked by India ink. The other 20 tubers were left uninoculated as controls. All of the tubers were held in a moist chamber for two days in order to give the fungus a chance to penetrate the tissues. All of the uninoculated eyes were then cut out of the inoculated tubers and all except two or three from each of the control tubers; they were then planted. The control tubers all grew, sending up 37 shoots, whereas only 5 shoots appeared from the inoculated tubers. All of the shoots appeared normal and remained healthy.

On May 22, 60 healthy Early Rose tubers of approximately the same size and with sprouts one-half inch to 1½ inches long were chosen for trial planting, 30 to serve as control and 30 to be inoculated. Of the inoculated tubers, 4 were treated by placing a drop of water containing the spores in the depression of a healthy uninjured eye, 16 were treated by placing the spore-bearing drop in an incision near an eye, and 10 had a bit of mycelium placed in a similar incision. The inoculated spots were marked as in the previous experiment and the tubers similarly treated, i. e., held two days in a moist chamber, the extra eyes removed, and the tubers then planted. The results were as shown in Table IV.

TABLE IV.—*Phytophthora inoculation of Early Rose tubers.*

Treatment given.	Number of tubers.	Shoots.	
		Number.	Description.
Spores in uninjured eye	4	0	....
Spores in incision near eye	16	3	Weak.
Mycelium in incision near eye	10	3	Do.
Control (not inoculated)	30	51	Strong.

All of the shoots from the inoculated tubers were weak and died within a short time, whereas the shoots from the control tubers matured normally and no trace of Phytophthora was detected on any of them. This is not surprising even though the fungus were present internally in the shoots from the inoculated tubers, since dry and hot weather continued during early summer and until after the death of the weak shoots from the inoculated tubers. Watering and partial shade were tried in the hope of inducing sporulation, but without success. These results, while not convincing in themselves, are in accord with Jensen's conclusion that when the young shoots are invaded by the fungus they are thereby weakened and may be killed outright before reaching the surface of the soil. The probability is that if the fungus overwinters as mycelium in tubers used for seed the first sporulation of the second season will appear on weak shoots which rise but a short distance above the surface of the soil and that from these shoots the spores will be scattered to the lower leaves of the overshadowing healthy plants. It is also to be noted, however, that much the same stages may occur in case the initial infection of the young shoots comes from the overwintering of a resting spore.

MODES OF DISSEMINATION IN THE FIELD.

The manner in which the rapid dissemination of the fungus is brought about following such primary infection is important as helping to determine what conditions favor the development of an epidemic. Moisture is, of course, essential for spore germination, and it is noteworthy that sporulation occurs abundantly only in a moist atmosphere. Probably the washing and dashing about by rain is the most effective agency for local dissemination. For longer distances two agencies probably cooperate, wind and insects. The former is so constantly operative that, while most spores carried by it must certainly perish by desiccation, enough may survive to carry the infection to distant plants.

The importance of insects in the dissemination of plant parasites has been clearly presented by Smith (1896) and others. In order to make a specific test of their ability so to function in the case of this fungus, the following observations were undertaken.

On the morning of July 15, 40 larvæ or slugs of the Colorado potato beetle were placed on Phytophthora-bearing potato leaves under a bell jar. That night the larvæ were transferred to two healthy potato plants, which were then covered by a bell jar until the next morning. The insects were then killed. The plants, which were growing in pots, were kept well removed from any other potato plants. After six days diseased areas appeared upon two leaves of one plant and one leaf of the other. The mature beetles by their more active habits and their migration on the wing are, of course, capable of carrying the Phytophthora spores to greater distances than the larvæ and doubtless are important agents in the spread of the fungus in potato fields, especially in the earlier stages of its development.

SPRAYING THE FOLIAGE A PRACTICAL REMEDY.

No plant disease has received so persistent and widespread attention as this in the search for effective remedies. The only measures which have given much return, or, indeed, which give large assurance of such to date, are foliage spraying and the development of disease-resistant varieties. Both of these measures have been so fully dealt with in previous publications (Jones, 1899, 1905; Stuart, 1906) that only the briefest summary is justifiable here.

Attention has already been called to the early recommendation of Morren (1845) of a mixture of copper sulphate, salt, and lime as a remedy to be sprinkled on the soil. Had he tested this on the foliage greater results might have followed. Since then practically every fungicide of promise has been tested by one or another experimenter upon potatoes. Freshly prepared Bordeaux mixture holds its place, however, as distinctly the best remedy. When rightly prepared and intelligently used it is a remarkably effective potato fungicide. The credit for the first demonstration of its value in controlling Phytophthora belongs to M. Jouet, who in 1885 used it on tomatoes in France. In 1888 Prillieux used it effectively on potatoes. He prepared a mixture containing 6 parts each of copper sulphate and lime in 100 parts of water which he applied to the potato foliage when the fungus made its first appearance in the field with apparent benefit, although in spite of it he lost about 25 per cent of his yield from rot. During the next three years, trials of this promising new remedy were made at several of the recently organized American experiment stations as well as in European countries other than France. Sorauer (1893) in Germany found that by spraying with Bordeaux mixture after each rain he could save all but 1 to 2 per cent of the tubers. Extensive experiments in England and Scotland under the auspices of the Royal Agricultural Society confirmed the results obtained in France and Germany. The most pronounced benefits from the experimental use of this mixture, and the most extensive applications in practice, have obtained in America. Probably this is in part due to the fact that this country has a variety of potato pests, especially the Colorado beetle, whose ravages have forced the progressive potato grower to use some kind of spray, and the Bordeaux mixture in combination with arsenical poisons has proved a remarkably effective panacea for the numerous other potato pests, insect and fungous, as well as for Phytophthora. At the Vermont experiment station the first trial of this mixture for the potato fungus was made in 1889 (Minott, 1890), and annual trials of spraying late or main-crop potatoes two or three times with Bordeaux mixture were continued for 20 years consecutively. A detailed review of this work is given by Lutman (1910). The averages from these trials are shown in Table V.

TABLE V.—*Averages of 20 years' trials in Vermont, showing gains from the use of Bordeaux mixture on late potatoes.*

Variety planted and date of planting.	Dates of spraying.	Yield per acre.		Gain per acre.	
		Sprayed.	Not sprayed.		
		Bushels.	*Bushels.*	*Bushels.*	*Per cent.*
White Star:					
May—, 1891	Aug. 26, Sept. 8	313	248	65	26
May 20, 1892	July 30, Aug. 13, 25	291	99	192	194
May 20, 1893	Aug. 1, 16, 29	338	114	224	196
Apr. 26. 1894	June 16, July 17, Aug. 30	323	251	72	29
May 20, 1895	July 25, Aug. 13, 31	389	219	170	78
Polaris:					
May 15, 1896	Aug. 7, 21	325	267	68	26
June 1, 1897	July 27, Aug. 17, 28	151	80	71	89
White Star:					
May 10, 1898	July 21, Aug. 10	238	112	126	112
Three varieties (average):					
May 18, 1899	July 26, Aug. 17, Sept. 8	229	161	68	42
Delaware:					
May 23, 1900	Aug. 4, 23	285	225	60	27
May 25, 1901	July 20, Aug. 21	170	54	116	215
May 15, 1902	Aug. 1, 20	298	164	134	82
Green Mountain:					
May 1, 1903	Aug. 10	361	237	124	52
Delaware:					
May 25, 1904	Aug. 1, Sept. 1	327	193	134	69
May 15, 1905	Aug. 2, 21	382	221	161	73
Green Mountain:					
May 27, 1906	Aug. 13, 22	133	101	32	32
May 1, 1907	July 16, 25, Aug. 8, 22	171	63	108	175
May 15, 1908	June 26, July 9, Aug. 6, 26	156	65	91	140
May 28. 1909	July 12, 23, Aug. 6, 27	243	188	55	29
May 9, 1910	July 11, 27, Aug. 15, 23, 30	240	202	38	18
Average for 20 years		268	163	105	64

The average gain for the 20 years of spraying was 105 bushels per acre. The greatest gain was in 1893, when three applications made in August increased the yield of marketable potatoes from 114 bushels to 338 bushels per acre, or nearly threefold. The loss that year on the unsprayed plat was almost wholly due to Phytophthora. In all places where Bordeaux mixture is used in the Northeastern States some gain is attributable to its beneficial action against other potato pests, especially the early-blight and the flea beetle, as well as to the indirect stimulating effect which it exercises. Similar evidence as to the profitableness of the regular use of this spray on potatoes has recently been furnished by the trials of Stewart, of New York, and Morse, of Maine. Stewart, French, McMurran, and Sirrine (1910) had an average increase of 102 bushels per acre during the seven years (1902–1909) they have experimented with potato spraying at the Geneva (N. Y.) station. Morse (Bul. 169, 1909) was able to reduce the rot from the 25 to 75 per cent occurring on unsprayed fields to 0.6 to 0.9 per cent where the spraying had been thorough. It is evident, therefore, that by the intelligent use of Bordeaux mixture both the foliage and the tubers of the potato can be practically insured against serious attacks from Phytophthora even when it is epidemic. The cost of this is small in proportion to the gain. Stewart (Stewart, French, McMurran, and Sirrine, 1910, p. 44), in farm practice in New York, found the average cost for seven years to be $4.82 per acre for the season. Nevertheless, the potato grower has the right to expect at least some measure of relief from this necessity for spraying. This relief may be expected in part from the development of more highly disease-resistant varieties and in part from the completion of our knowledge of the life history of the fungus. Work like that now in progress on the life history in time should remove the last vestige of the breastwork which as yet obscures the location of the foe during certain seasons. The remaining pages of this bulletin contain the records of some attempts to further our knowledge along both of these lines.

GROWTH OF THE FUNGUS IN PURE CULTURE.

EARLIER TRIALS IN EUROPE.

In the earlier studies of *Phytophthora infestans*, 1860 to 1875, of course no attempt was made to get it into pure culture, since such a thing was unknown at that time. The only aim during that period was to get it and keep it comparatively free for a short time from contamination by other fungi. The growth of the fungus on the leaves and aerial parts of the plant had been repeatedly observed since its discovery by Von Martius and the description of the species in

1845 by Montagne. De Bary (1863, p. 94) was apparently the first to obtain the fungus with anything like a pure growth of mycelium and conidiophores on the tubers. His method, which has become the classical one for demonstrating the presence and methods of fruiting of the fungus, consists in cutting open an infected tuber and keeping it under a bell jar where the surface will continue damp. In a few days, under favorable conditions, a growth of Phytophthora will appear on such surfaces and the mycelium and fruiting branches can be obtained in a fairly pure state. De Bary (1863, p. 64) was able to transfer the conidia either to the uninjured tuber or to the cut surface of other uninfected potatoes and cause infection.

Since the fungus has been generally regarded as a strict parasite, without any saprophytic phase in its life history, it has been commonly considered impossible to induce it to grow on anything but the living potato or potato plant. Recent work, however, has shown that this conception is an erroneous one and that, while it is strongly parasitic in its habits, it is not an obligate parasite. The range of its saprophytism is rather narrow, however, as will appear later.

The earliest attempt at growing the fungus on substrata other than living potato tubers and leaves was that of Hecke (1898), who cultivated the Phytophthora on decoctions of plums, of tomatoes, of cherries, and of potato leaves, but was unable to induce it to grow on infusions thickened with gelatin. He also found that the fungus could not stand a higher concentration than 1.5 to 3 per cent of dry substance, while a still lower concentration favored its growth.

The next account of the isolation and cultivation of the potato fungus was that of Matruchot and Molliard (1903), who succeeded in growing it on solid media. They were able to transfer it from the fresh surfaces of infected potatoes kept under a bell jar, as described by De Bary, to sterile plugs of potato in test tubes. The growth and fructification obtained under these conditions were normal and abundant. Plugs of pumpkin and muskmelon (melon d'Espagne) gave practically as rapid a growth and as large a quantity of fruiting branches. The curious fact was brought out that the fungus would not grow or produce conidia on potato plugs sterilized at 115° C., while it would grow almost as well and produce as many conidia on the cooked pumpkin plugs as on the raw ones, and almost as well on the cooked muskmelon as on the raw. The cause for this difference they believe to lie in the fact that the superheated steam so swells the starch grains of the potato that the fungus finds it mechanically impossible to push its hyphæ between them. The best artificial media for its growth were found to be potato or pumpkin broths or such broths thickened with gelatin. In all these broths fructifications occurred abundantly.

MORE RECENT TRIALS IN AMERICA.

In 1904, and before the results of the preceding workers came to our attention, pure cultures of the potato fungus were obtained on sterile potato blocks in the Vermont laboratory, and since that date it has been carried continuously in pure cultures, during the earlier part of the time on potato blocks in tubes, but more recently on gelatin or agar media. Before discussing our methods and results in detail it will be helpful to review the work of Dr. G. P. Clinton, of the Connecticut station, who has meanwhile contributed some helpful facts and methods along similar lines.[1] Clinton (1906) confirmed Matruchot and Molliard's results on the cultivation of the fungus on plugs of living tissue of potato or pumpkin. He found further that the fungus would grow better on sterilized corn meal or on a mixture of ground green Lima-bean pods and seeds with corn meal than on any other of the artificial media he tested. Some growth was obtained on agar cultures to which various ingredients had been added, but on the whole they were unsatisfactory, potato and pumpkin juice being better. In a more recent paper Clinton (1908) reports upon further trials in the cultivation of the fungus. In these trials he found that the soluble substances produced a medium on which the fungus grew and fruited as well as on living plugs of the potato or pumpkin. He also tried a number of other media, among them the potato-juice gelatin in use in the Vermont laboratory, but found it not to be a very good medium because the surface layer would dry out and it was difficult to get the fungus started.

In our Vermont laboratories *Phytophthora infestans* has been grown continuously in pure cultures since 1904 by the writers and others, as stated in the introduction to this bulletin. The chief incentive at the outset was the possibility of the discovery of oospores or other resting spores. Later the aim has been, in addition, to contribute something to the knowledge of the occurrence and nature of disease resistance to this fungus, as shown by certain potato varieties. Progress toward these goals was, however, made very slow by the difficulties encountered in the perfection of culture methods and media, and perhaps the most important gains to date lie in the development of cultural methods and their application to the testing of disease resistance. In the succeeding pages the aim has been to outline these attempts in sufficient detail so that anyone wishing to repeat or continue this line of investigation may be able to profit as far as practicable from our experience. Therefore, the general methods and results of the cultural studies will be outlined before special attention is given to the matters of resting spores and disease resistance.

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[1] Clinton's latest results (1910), including an important new culture medium, have come to hand just as this bulletin is going to the printer. A brief review of these results is inserted on a later page.

DETAILS OF TRIALS MADE AT THE VERMONT STATION.

SOURCES OF THE PURE CULTURES EMPLOYED.

In connection with these studies pure cultures have been obtained from tubers from different sources, including several from Vermont, two from Connecticut (G. P. Clinton, one tuber and one culture), one each from Maine (W. J. Morse) and Pennsylvania (W. A. Orton), two from England, and one each from Holland, Germany, Ireland, and Scotland. The methods used in isolating and cultivating the fungus will be given in sufficient detail so that anyone desiring to do so may be able to repeat the work. The cultures have been secured in all cases from tubers showing the dry-rot, those in the early stages being chosen where practicable. The tuber selected is split open with a sterile knife, placed under a bell jar in a moist atmosphere to favor the development of the fruiting fungus on the freshly cut surface, and as soon as the growth appears it is transferred to sterile raw-potato cylinders prepared as described later. Bacterial contaminations often occur which necessitate several further transfers for their elimination, and this is made easier by the use of the bean-agar medium described later.

VARIOUS CULTURE MEDIA TESTED.

In the course of these studies a wide variety of culture media has been tested. Some of these media proved more or less favorable for the growth of Phytophthora, while others were entirely unsuited. Normal growth and fruiting have been obtained on raw-potato and pumpkin blocks, potato gelatin, and Lima-bean agar. On certain other media, such as pumpkin agar, pumpkin gelatin, and some of the synthetic media, there was some growth, with few or no conidia, while on many others no growth was apparent. In considering the details as to the behavior on these media it will prove helpful to group them as follows: (1) Raw and cooked vegetables; (2) vegetable broths, either alone or with gelatin or agar; (3) synthetic liquid media; (4) synthetic media with agar or gelatin; (5) synthetic liquid media and silicate jelly. All cultures were carried at 18° to 20° C. unless otherwise specified.

GROWTH ON VEGETABLE TISSUES.

The media tested in these trials included raw or living potato tubers, raw muskmelon and pumpkin rinds, parsnip roots, and also cooked tissues from different parts of the potato and pumpkin. The raw potatoes were prepared as follows: Medium-sized sound tubers were washed, immersed 10 minutes in a 0.1 per cent solution of mercuric chlorid to disinfect, the surface layer was cut away with a knife kept sterile by repeated flaming, and blocks about 1 by 1 by 4 centimeters in size were cut from the interior. Each such block was then dropped into a sterile culture tube which contained about 1 cubic centimeter of water, either with or without absorbent cotton in the bottom. The medium was then allowed to remain at least three days to test sterility before inoculation. The other raw vegetables were prepared in essentially the same way. The cooked vegetables were prepared by using similar blocks covered to about one-third their depth with water sterilized by exposure to flowing steam on three consecutive days. Inoculations upon such raw-potato blocks cut from tubers of Early Rose, Green Mountain, or other varieties favorable for the fungus will yield a prompt growth which is in full fruit in 5 or 6 days, and by 10 days has reached its maximum, when the surface of the potato is often completely hidden under the cottony mycelium (Pl. IX). Thereafter the culture may soon die out, although the longevity of such potato cultures may be surprisingly great, especially if desiccation is checked. Thus, one such culture which had been sealed for 7 months was found to be living when opened. Where invaded by the fungus the potato tissue is usually discolored to brown or black for several cells in depth, although the degree of this discoloration varies widely with varieties and in some it is very slight. It must be that Matruchot and Molliard (1903, p. 542) used varieties of this latter type, since they observed no discoloration. In vigorous cultures, 5 to 8 days old, droplets of clear brownish liquid exudate will frequently appear upon the surface of the mycelial layer, apparently as a result of a normal bleeding process comparable to that observed in Pilobus and other fungi (Pfeffer, Eng. ed., p. 275). In order better to observe this exudate, cultures were made on large slices of potato in petri dishes. Upon these slices the exudate appeared in quantity while the underlying potato tissues were shrunken in proportion, indicating that water was being withdrawn from these tissues to supply the loss to the fungus above. Sufficient of this exudate was collected for titration with phenolphthalein. It was found to be slightly acid in reaction, but less so than the normal potato juice, showing that in passing through the fungus it is modified toward alkalinity. A comparison of blocks cut from just below the surface of the large-sized tubers with others from the center of the same failed to show any difference in the resulting growth. There may, however, be a marked difference in the growth on blocks cut from tubers of different varieties. The consideration of this feature is given further attention under "Disease resistance of potatoes" (p. 69).

In contrast with this vigorous normal growth on raw potato is the fact that repeated trials have failed to obtain any growth on cooked potato. As already stated, Matruchot and Molliard (1903, p. 541), who had like results, attributed this immunity to the mechanical obstruction due to the swelling of the starch grains by cooking, which prevented the penetration of the fungus. Partial confirmation of this idea is found in the fact that some growth is obtained in cooked potato broth.

On raw pumpkin the growth was much slower than on potato, but ultimately it was fair with normal conidial fructification. On cooked pumpkin it was somewhat weaker, but gave a moderate crop of conidia.

GROWTH ON VEGETABLE EXTRACTS EITHER ALONE OR WITH GELATIN OR AGAR.

This phase of the cultural studies has at the same time suggested so much of promise and presented so many difficulties in development that it has received a relatively large amount of attention. Potato juice was pressed from the living potato tissues, leaf and tuber, and sterilized by passing through a Pasteur-Chamberland bougie into a sterile vessel. The leaves of both susceptible and resistant varieties were tried as a source of this juice, as well as the tubers of the same varieties. Juice was extracted both from the surface tissues and from those of the interior of the potato tuber. The results are taken up in detail under "Disease resistance of potatoes" (p. 69) and so will be only briefly summarized here. Little difference was apparent in the growth on the juice from these various sources. The growth in all cases was slight, slow in developing, entirely submerged, with few conidia, and these abnormal. When the potato extract from leaf or tuber was sterilized in the steam cooker, the growth obtained was about the same at the outset, but ultimately became somewhat more than that on the raw juice.

Broths from the potato and from various other vegetables were also tested in combination with gelatin or agar. This series included the following: Potato-broth gelatin, potato-broth agar, pumpkin-broth gelatin, pumpkin-broth agar, Lima-bean agar, prune-juice agar, starch gelatin, mannite gelatin, and various percentages of gelatin in pure water.

The potato gelatin was made up as follows: 1,000 grams of Green Mountain potatoes, after being washed, were cut into small blocks in 1,500 cubic centimeters of water. After cooking in the steamer for 1½ hours they were steamed in the autoclave at 2 pounds pressure for 1 hour. The liquid was separated by filtration through filter paper and Nelson's gelatin added. Trials of various strengths showed that 10 per cent of gelatin gave the best results, although 7½ and 5 per cent gave results nearly as good. The gelatin was then dissolved by heating the medium in the steamer, after which it was cleared with white of egg, passed through filter paper by suction, and sterilized in the autoclave at not to exceed 4 pounds pressure for 15 minutes. A higher pressure or longer time prevented the gelatin from solidifying. Submerged inoculations were made in the earlier trials, either immediately under the surface or at the bottom of the tube. The gelatin was melted to permit the bottom inoculations. The growth in the potato gelatin medium, so handled, was fairly good and the hyphæ were normal in appearance. The production of the conidia was largely suppressed, whether in submerged cultures or in inoculations near the surface. In their stead there appeared the resting-spore development, which will be described in detail on a subsequent page. It was found that slant cultures could be made with this medium by increasing the gelatin to 12 per cent and that, when surface inoculations were made upon these, fairly abundant aerial growth developed. This result is in contrast to the experience of Clinton (1908, p. 899) with potato gelatin, he having found that it was a very poor medium, especially for aerial growth. Minor differences in medium or manipulation may account for this.

Potato-broth agar produced a slow growth which was ultimately fair but with fewer conidia than were produced on potato gelatin. Lima-bean agar has proved much better. The Lima-bean agar which has given us the best results is a modification of that of Clinton (1908, p. 898) and prepared as follows: 50 grams of Lima beans, after being ground as fine as possible in a meat chopper, were soaked for one-half hour in 500 cubic centimeters of tepid water, allowed to simmer for half an hour in the steamer, and the juice then strained through a cloth. After restoring the volume of broth to 500 cubic centimeters, 1 per cent of agar was dissolved in it by heating in the autoclave. Titration has shown this medium to have a reaction of about +4 Fuller's scale. The fungus forms on this medium in four to five days a good aerial growth of mycelium with many normal conidia. The resting spores, as later described, have been found on this medium, though less commonly than in the potato gelatin. This medium has proved to be especially useful for carrying the stock cultures of the different strains, since it is easier to prepare than raw-potato blocks and the fungus does not so soon suffer from desiccation. Therefore it has been exclusively used for this purpose during the latter part of the work.

On the pumpkin-broth agar and gelatin the growth while slow was ultimately fair. The development on these media has been chiefly aerial with some conidia, but in much smaller number than on the potato-gelatin slants and the Lima-bean agar. On prune-juice agar there was no growth, showing that Phytophthora is unable to avail itself of the rich store of sugar of the prune. It is interesting to note that a small growth was secured in tubes containing simply gelatin (10 per cent) in water, this growth being estimated at two-fifths of that on potato gelatin. The addition of 0.5 of 1 per cent of starch to this gelatin had no material influence on the growth nor did the addition of 0.5 of 1 per cent of mannite.

GROWTH ON LIQUID SYNTHETIC MEDIA.

In addition to attempting to grow the fungus on some of the standard synthetic solutions, such as those of Uschinsky and Knopp, a further attempt was made to put together chemicals representing approximately the compounds found in the potato tuber. In this work the potato analyses of Watson (1895, p. 194) were used as a basis. He analyzed the ash of eight varieties of potatoes, Early Essex, Beauty of Hebron, Burbank, Green Mountain, Charles Downing, Early Rose, Early Ohio, and Sunrise, and gives the average of each of the constituents for these varieties to be as shown in Table VI.

TABLE VI.—*Average constituents of eight varieties of potato tubers.*

Constituents.	Average.	Constituents.	Average.
	Per cent.		*Per cent.*
Moisture	76.94	Magnesium (MgO)	0.054
Ash	1.35	Sulphuric acid (SO_3)	.076
Nitrogen	.394	Soda (Na_2O)	.068
Phosphoric acid (P_2O_5)	.154	Chlorin	.048
Potash (K_2O)	.828	Insoluble matter	.014
Lime (CaO)	.010		

In making up our liquid media it was practicable only to approximate the above composition percentages. Each of the combinations used contained some carbon compound and, if no nitrogen was supplied in the inorganic salts, some nitrogenous organic compound was added, such as asparagin. The growth that was obtained on these broths contributed nothing positive toward the main problems in mind, but they have interest as showing that a fairly normal growth of this fungus may be had on purely synthetic media and they contribute some facts of general interest concerning the nutrition of fungi. The composition of these various media and the resulting growth are shown in Table VII.

Table VII.—*Synthetic broths used for testing the growth of Phytophthora infestans.*

No. of broth.	Constituents added to 1,000 cubic centimeters of water.													Growth.
	Potassium phosphate K_2HPO_4.	Ammonium phosphate $(NH_4)_3PO_4$.	Potassium chlorid KCl.	Magnesium sulphate $MgSO_4$.	Calcium carbonate $CaCO_3$.	Potassium nitrate KNO_3.	Calcium nitrate $Ca(NO_3)_2$.	Calcium chlorid $CaCl_2$.	Glycerin.	Mannite.	Asparagin.	Potato starch.	Urea.	
I	1.00	10.00	.....	0.10	.....	.....	.....	.....	5.00	.....	.....	.....	.....	None.
II	1.00	10.00	.....	.10	.....	.....	.....	.....	.....	20.00	.....	.....	.....	Do.
III	1.00	5.00	.....	.10	.....	.....	1.00	.....	.....	20.00	.....	.....	.....	Do.
IV	.25	.....	0.05	.10	0.025	0.50	.....	.....	.....	.....	0.50	.....	.....	Good.[1]
V	.25	.....	.05	.10	.025	1.00	.....	.....	.....	.....	.....	.....	.....	None.
VI	.25	.....	.05	.10	.025	.....	.....	.....	.....	.....	1.00	.....	.....	Do.
VII	.25	.....	.05	.10	.025	1.00	.....	.....	.....	.....	.....	0.25	.....	Do.
VIII	.25	.....	.50	.10	.025	.50	.....	.....	.....	.....	.....	.....	0.50	Do.
IX	.25	.....	.50	.10	.025	.50	.....	.....	.....	.....	.....	.....	1.00	Do.
X	.25	.....	.05	.10	.025	.50	.....	.....	.....	.50	.....	.....	.....	Slight.
XI	.25	.....	.05	.10	.025	.....	.....	.....	.....	.50	.50	.....	.....	Good.[2]
XII	.25	.....	.05	.10	.025	.50	.....	.....	.....	.50	.....	.....	.50	Slight.
XIII	.25	.....	.05	.10	.025	.....	.....	.....	.....	.50	.....	.....	.50	Very slight.
XIV	.25	.....	.05	.10	.025	.50	.....	.....	.....	.50	.50	.....	.....	Fair.
XV	.25	.....	.....	.10	.025	.50	.....	.....	.....	.....	.50	.....	.....	Do.
XVI	.25	.....	.05	.10	.....	.50	.....	.....	.....	.....	.50	.....	.....	Do.[3]
XVII	.25	.....	.....	.10	.....	.50	.....	.....	.....	.....	.50	.....	.....	(4).
XVIII	.25	.....	.....	.10	.....	.50	.....	0.08	.....	.....	.50	.....	.....	(5).
XIX	.25	.....	.....	.10	.....	.50	.08	.....	.....	.....	.50	.....	.....	Slight.
XX	.25	.....	.....	.10	.....	.....	.50	.....	.....	.....	.50	.....	.....	None.
XXI	.25	.....	.....	.10	.....	.....	.50	.08	.....	.....	.50	.....	.....	Slight.
XXII	.25	.....	.50	.10	.....	.....	.50	.....	.....	.....	.50	.....	.....	Do.
XXIII	.75	.....	.15	.30	.075	1.50	.....	.....	.....	.....	1.50	.....	.....	(6).
XXIV	2.50	.....	.50	1.00	.25	5.00	.....	.....	.....	.....	5.00	.....	.....	None.[7]
XXV	.25	.....	.05	.10	.025	.50	.....	.....	.....	.....	.50	.....	.....	Same as IV.[8]
XXVI	.025	.....	.005	.01	.0025	.05	.....	.....	.....	.....	.05	.....	.....	Fair.[9]

[1] Best liquid medium tried.
[2] About like that on medium IV.
[3] Hardly as good as that on IV.
[4] Good growth in two cases; in others varied from slight to fair.
[5] Growth varied in the different tubes from fair to good.
[6] This medium is IV×3. Fair growth in a few; in some cases very slight; very few conidia.
[7] This medium is IV×10.
[8] This medium is the same as IV except that untested "C. P." chemicals were used without verification.
[9] This medium is IV÷10.

The following comments will help in the interpretation of the table. It is noteworthy that the best growth was in No. IV, which is as nearly a duplicate of the analysis of potato ash as was found practicable with chemicals of known composition. It was found that a dilution of this medium to one-tenth of its original strength produced practically as much growth as the original medium. On the other hand, increasing the strength of the solution by using three times the quantity of chemicals still gave a fair growth, but with the broth that was made with ten times the quantity of chemicals no growth resulted. From this it seems that *Phytophthora infestans* can find a good food supply even in a very dilute solution, where the osmotic pressure is comparatively low, and that it is unable to grow in a solution with a relatively high osmotic pressure. This result is, of course, to be expected from the chemical composition of its natural substratum, the potato, where the osmotic pressure produced by the inorganic salts is very low, and it is also in accord with the observation of Hecke (1898), already cited.

It may safely be assumed that one of the reasons for failure in Nos. I, II, and III is that the chemicals used were sufficient to produce osmotic pressure too high for the growth of the fungus. They contained 16.1 to 31.1 grams of soluble material as against 14.25 grams in No. XXIV, in which the concentration of the solution is clearly the cause of failure, as may be seen by comparison with No. IV. The absence of a suitable supply of nitrogen suggests itself as another possible explanation. In No. I nitrogen is supplied as ammonium phosphate and also as an impurity of the glycerin. In No. II ammonium phosphate is the only source of nitrogen, while in No. III calcium nitrate is added. The presence of glycerin may have inhibited growth in No. I, and the results with No. XIX suggest that calcium nitrate may have been a disadvantage in No. III. It may be noted that No. I is a modified Fermi solution.

When compared with No. IV, the results from No. V show that in the combinations employed asparagin is essential for growth, and the results from No. VI show that potassium nitrate is needed, or that an excess of asparagin inhibits growth. No. VII would seem to show that starch can not be utilized in place of asparagin, and Nos. VIII and IX would show the same concerning urea. In No. X it appears that mannite can replace asparagin to a very slight extent. It is hard to understand just why growth took place in No. XI and not in No. VI, but apparently the combination of mannite and asparagin sufficed to fill the lack of potassium nitrate.

From the results on these broths and the others not specifically mentioned it would seem as though it can be safely assumed that mannite, potato starch, urea, and calcium nitrate are not of appreciable use as a source of food for *Phytophthora infestans*. It would also appear that asparagin, magnesium sulphate, acid potassium phosphate, and possibly potassium chlorid are essential to its growth.

The remaining broths, Nos. XIV to XXII, all contained asparagin and on all of them more or less growth appeared, the amount varying with the other chemicals in the solution. The best of these are Nos. XIV to XVIII, inclusive. In No. XIX the addition of the calcium nitrate seems to have an inhibiting effect on the fungus and the growth is slight; at any rate the growth is not equal to that made in Nos. XIV and XV with calcium carbonate. The entire absence of calcium in No. XVII did not seem to prevent a good growth. This may be interpreted as a confirmation of the work of A. Mayer[1] on yeast, or Raulin[1] on Aspergillus, and Winogradsky[2] on *Mycoderma vini*, none of whom found calcium necessary for fungous growth. Nos. XX and XXI show, probably as a result of the lack of potassium, a very slight growth, while No. XXII with the potassium supplied as potassium chlorid seems to have had its growth inhibited by the addition of the calcium nitrate, as does No. XIX.

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[1] Mayer, A. E. Untersuchungen über die Alkoholischegährung, den Staffbedarf und den Stoffwechsel der Hefepflanze. Heidelberg, 1868, p. 44.

While the results with these broths are not complete, they indicate that *Phytophthora infestans* is limited to certain combinations of chemicals as sources of carbon, nitrogen, and energy. The only really efficient single carrier of these which was found is asparagin, and the availability of this substance seems to be dependent upon the presence of other chemicals, as may be seen by a comparison of Nos. IV, VI, and XI. In No. IV asparagin is the only source of carbon and energy; in No. XI it is the only source of nitrogen; in No. VI it is the only source of any of the three. It will be noted that good growth appeared in No. IV and in No. XI, but no growth in No. VI. Neither mannite nor potato starch could take the place of asparagin, even when combined with nitrogen in the form of potassium nitrate, and urea was not more suitable even when combined with mannite, as in No. XIII. The results also seem to show that certain inorganic salts such as calcium nitrate will have an inhibiting effect on the growth even when all the other food constituents are supplied, as in XXII.

GROWTH ON SYNTHETIC MEDIA WITH THE ADDITION OF AGAR OR GELATIN.

In connection with these trials a number of the standard liquid solutions for the cultivation of fungi were solidified with agar or gelatin and Phytophthora was tried on them. These included the Fermi, Uschinsky, and Knopp solutions and a number of modifications of a solution given by Heinemann (1907) as a potato substitute culture medium.

The regular Fermi gelatin was made by the addition of 10 grams of Nelson's photographic gelatin to 100 c. c. of Fermi's solution, the solution then being cleared by the white of egg. A modification was made in a similar way, except that it contained only 10 c. c. of Fermi's solution, to which 90 c. c. of water and 10 grams of gelatin were added.

The Uschinsky gelatin was made in the same way, using 100 c. c. of Uschinsky solution and 10 grams of gelatin.

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[1] Raulin, J. Études Chemiques sur la Végétation. Annales des Sciences Naturelles. Botanique, ser. 5, vol. 11, 1869, p. 224.

[2] Winogradsky, S. Ueber die Wirkung äusserer Einflüsse auf die Entwicklung von Mycoderma Vini. (Arbeiten der St. Petersburger Naturforschende Gesellschaft, vol. 14, pt. 2, 1884, pp. 132–135.) (Russian.) Abstract in Botanisches Centralblatt, vol. 20, 1884, p. 167.

The Knopp gelatin consisted of 10 grams of gelatin similarly combined with the following solution: Calcium nitrate, 0.068 grams; potassium nitrate, 0.017 grams; magnesium sulphate, 0.017 grams; potassium phosphate, 0.017 grams; water, 100 c. c.

Heinemann's medium, as given by him (1907), contained the following: Magnesium sulphate, 2 grams; calcium chlorid, 2 grams; ammonium lactate, 2 grams; peptone, 10 grams; agar, 10 grams; starch, 10 grams; water (to make a total of 1,000 grams), 944 c. c.

In our procedure the same constituents were used, except for the omission of the peptone and the addition of potassium and sodium phosphate, but they were made up in three parts so that the proportion of agar, chemicals, and starch could be varied, as follows:

(1) Ten grams of agar in 400 c. c. of distilled water.

(2) Two grams each of dipotassium hydrogen phosphate, disodium hydrogen phosphate, magnesium sulphate, calcium chlorid, ammonium lactate; water, 200 c. c.

(3) Thirty grams of starch in 200 c. c. of water.

Five different mixtures of these three parts were used:

(A) 120 c. c. of 1; 40 c. c. of 2; 40 c. c. of distilled water.
(B) 120 c. c. of 1; 40 c. c. of 2; 40 c. c. of 3.
(C) 60 c. c. of 1; 40 c. c. of 2; 80 c. c. of distilled water.
(D) 80 c. c. of 1; 40 c. c. of 2; 40 c. c. of 3; 40 c. c. of distilled water.
(E) 40 c. c. of 1; 40 c. c. of 2; 40 c. c. of 3; 80 c. c. of distilled water.

Heinemann's medium, as he made it, is 5 per cent acid, but these modifications were all titrated and made neutral to phenolphthalein by the addition of sodium hydroxid.

The growth was only slight on the Fermi, Uschinsky, and Knopp gelatins and no production of conidia occurred. On the modifications of Heinemann's substitutes for potato a fair growth appeared after three days in the tubes of three of these variations (A, C, and E); a somewhat smaller growth appeared in another (B), and a slight growth in the fifth (D). A second titration of these media showed this last (D) to be slightly more acid than the others, and the difference noted was attributed to this fact. The other fact brought out was that the fungus thrived better in a medium without starch. The starch, even though in small amount, may present here the same mechanical obstacles to the advance of the fungus that it does in the cooked potato. The mycelial threads were found in these synthetic media to contain an abnormal amount of fat globules and to have penetrated the substratum to a considerable extent. In some cultures, where there was almost no visible growth, the medium was melted and the agar and starch, which rendered the medium semiopaque, were washed away, whereupon an abundant mycelial growth was revealed. Lateral branches of this mycelium, which were richly supplied with protoplasm, often showed 3 to 6 constrictions at intervals of 20 to 30 microns, which apparently represented abortive attempts at the formation of the resting spores noted in other cultures. The presence of an unusual amount of fat in the hyphæ is an indication that the fungus was not in normal condition and that none of these substrata are satisfactory substitutes for potato.

GROWTH ON SYNTHETIC MEDIA WITH SILICATE JELLY.

In order to compare the growth on solid and liquid media where the nutritive elements are the same, recourse was had to the use of silicate jelly. The synthetic broths Nos. I to IV, the constituents of which are shown in Table VII, were used, the chemicals being dissolved in only one-tenth the usual amount of water, and 10 c. c. of each was added to 90 c. c. of the silicate-jelly mixture. Growth appeared on all of these solidified synthetic media, the best being on No. IV. These growths did not, however, differ appreciably from those obtained on the corresponding liquid media either in quantity or character. This indicates that the fungus is indifferent as to whether its food occurs in a liquid or solid substratum and that a gelatinous material of the consistency of silicate jelly offers no serious obstacle to its progress.

BIOCHEMICAL AND THERMAL RELATIONS OF PHYTOPHTHORA INFESTANS.

In connection with the cultural studies already described, some observations were also made on the relations of varying degrees of acidity and alkalinity of the medium to the vigor and character of growth, as well as upon the temperature relations. These observations, while not complete in all respects, give some interesting evidence as to the resistance of the fungus to extremes of temperature and also as to its sensitiveness to the reaction of the substratum.

RELATIONS TO ACIDS AND ALKALIS.

The growths obtained on the various media used in the preceding studies, of which the reactions ranged from +14 to 0 Fuller's scale, have served to indicate that the fungus will survive a fairly wide range, being scarcely more sensitive to acids and alkalis than most of the bacterial plant pathogenes. In order to make more critical demonstrations upon this point, a special series of cultures was run on Lima-bean agar that had been made neutral to phenolphthalein and then reenforced with definite amounts of acid and alkali. Malic acid was chosen as the acid to use, since Snyder (1896, p. 85) shows it to be the one normally present in the potato tuber. Sodium hydroxid was used as the alkali. It was found that the carbon dioxid of the laboratory atmosphere seriously altered the reaction in such alkaline culture tubes before the end of the five to seven days which the fungus required for characteristic growth. To avoid this difficulty, the inoculated alkaline tubes after inoculation were promptly placed in sealed glass jars, together with a tube of concentrated potassium hydroxid solution, and they were retitrated at the end of the experiment. Table VIII gives the results, the titrations being expressed according to Fuller's scale.

TABLE VIII.—*Relative rate of growth of Phytophthora infestans in acid and alkaline media.*

Titration at beginning of experiment.	Retitration at end of experiment.	Growth during experiment.
+40	+37.5	No growth.
+30	+25	Very little growth.
+20	+15	Some growth; no fruiting.
+10	+10	Fair growth; fruiting much less than on neutral medium.
0	+ 1	Growth and fruiting abundant.
− 5	− 3	Fair growth, but much less than on neutral medium; no fruiting.
−10	− 4	Fair growth in 2 tubes, slight in the other 6; no fruiting.
−15	− 8	Very slight growth.
−20	−12	No growth apparent.

From these results it will be seen that this fungus is more susceptible to the alkali than to the acid. The first effect of acid and alkali alike was to prevent the formation of the fruiting branches; but while the smallest amount, viz, −3, of the alkali did this, it required +15 acid to produce the same result. In contrast with this result was the wide range over which some vegetative growth may take place, viz, at least −8 to +25. The acid condition of the potato tissues would lead one to expect, of course, that the preponderance would be toward the acid end of the scale, but the inhibiting effect of even the smallest per cent of sodium hydroxid was so marked as to suggest that the lime present in Bordeaux mixture may have more fungicidal value than is generally supposed.

Acknowledgments are due to Dr. Mel T. Cook, of the Delaware Agricultural Experiment Station, for determining the effect of tannic acid upon the development of Phytophthora and for placing the results of his investigations at our disposal. He grew cultures of the fungus, sent for this purpose from our laboratory, on Lima-bean agar made according to the formula already given. To this medium tannin was added in varying proportions from 0 to 0.6 per cent, as follows: 0, 0.0067, 0.007, 0.0083, 0.01, 0.0125, 0.0167, 0.025, 0.05, 0.1, 0.2, 0.4, and 0.6 per cent. The experiment was repeated several times. Some variation was shown in the results, but the growth was better in all media without tannin than where even the smallest amount of tannin was present. Tannin of the five lesser strengths, 0.0067 to 0.0125 per cent, gave a somewhat smaller growth, but it still was fairly luxuriant and practically the same throughout. From 0.0167 to 0.05

per cent the growth was appreciably less than in the weaker series but without much difference within these limits. From this point there was a marked decline in vigor and from 0.2 to 0.6 per cent, inclusive, there was practically no growth at all. Dr. Cook's primary aim in his studies, which have included many other fungi (1910, pp. 751–752), is to learn whether tannin may be a factor in determining relative disease resistance. While this may be the case with certain hosts and parasites it seems hardly probable with the potato, since its normal tannin content is very low.

THERMAL RELATIONS.

Considerable work has been done by previous investigators on the temperature limits for the life and growth of *Phytophthora infestans*, and these investigations supplemented by the following studies show that its growth is favored by a relatively low temperature while the fungus survives a lower temperature at least than the host plant. Jensen (1887) concluded from his trials that a temperature of 26° C. was fatal to the mycelium in the tubers, while only 25° C. was necessary to kill the spores. Jensen's conclusions as to the probable relation of this thermal death point to the delay in the transfer of the fungus from South America to Europe were reviewed earlier in this bulletin, as was also his ingenious method of tuber disinfection by dry heat. More recently Matruchot and Molliard (1903, p. 524) report that growth in culture stops at 30° C., but they did not determine the thermal death point.

Our own determinations of the thermal death point of the fungus lead us to place it somewhat higher than Jensen did; but the methods used are not strictly comparable, since our trials were made with cultures in potato gelatin. Four strains were tested, one tube of each strain being subjected to each temperature. After inoculation the gelatin in these tubes was carefully warmed to the melting point, control tubes being similarly melted at the same time. The experimental tubes were then immersed in a water bath the temperature of which could be controlled to one-tenth of a degree centigrade. The tubes were immersed four-fifths of their length and a thermometer was placed in a control tube beside them. The tubes were exposed for 10 minutes after the temperature inside the control tube had reached the desired point.

Exposures were made at temperatures ranging from 29° to 50° C. No inhibiting effects resulted from such heating at temperatures below 37° C., but some of the tubes carried above this temperature failed to grow. The lack of uniformity in these results was attributed to the fact that the culture tubes used in these trials were thick walled and not very uniform. A second trial was therefore made, using very thin-walled tubes. Good growths appeared in all tubes exposed to temperatures up to 40° C., but beyond this the results as to growth were doubtful.

The ability of the fungus to withstand cold is important in view of its life history in its native habitat, where it must pass the period of dormancy in some way in the soil at relatively low temperatures. Matruchot and Molliard (1903, p. 542) found that the growth was rapid at the average temperature of their laboratory (about 15° C.). The best temperature for good growth in tube cultures on raw-potato cylinders or other media was found in our trials to be about 16° to 18° C. The growth of the fungus at low temperatures was tested by the following experiment: Forty tubes of Lima-bean agar after inoculation with the Phytophthora were placed in four compartments of a low-temperature incubator, 10 tubes being placed at each temperature. Examinations and comparisons were made at intervals up to 22 days. A similar experiment was conducted with high temperatures. The results are shown in Table IX.

TABLE IX.—*Experiments showing growth of Phytophthora at different temperatures on Lima-bean agar.*

Experiments at low temperatures.			Experiments at high temperatures.		
Compartment.	Temperature.	Growth.	Compartment.	Temperature.	Growth.
	° C.			° C.	
1.......	3 to 5	None perceptible.	1......	30	None apparent.
2.......	10 to 11	Fair after 22 days, but slow in appearing.	2......	27	Fair; no fruiting.
			3......	25	Do.
3.......	16 to 18	Abundant; much fruiting.	4......	23	Good; a little fruiting.
4.......	18 to 19	Do.	5......	21	Good; abundant fruiting.

Some attempts were made to determine the low thermal death point of Phytophthora in potato-gelatin cultures. The results indicate that the fungus in such cultures will withstand freezing temperatures fatal to the potato tuber. Since, however, only one series of trials was made it is deemed best to withhold definite conclusions until this work can be repeated.

PRODUCTION OF RESTING SPORES BY PHYTOPHTHORA INFESTANS.[1]

The members of the group to which this potato fungus belongs typically produce sexual spores, oospores, which function as resting spores. One of the keenest controversies in mycological history has concerned the question as to whether *Phytophthora infestans* produces such resting spores or whether, on the contrary, it is wholly dependent for overwintering on the mycelium infesting potato tubers. De Bary in his early studies had this question in mind, but his researches (1876) failed to discover any form of resting spore. W. G. Smith (1875, 1876) later found bodies which he said were such oospores, and Vize, Broome, Plowright (Smith, 1876), and other English botanists accepted his evidence. On the other hand De Bary disputed Smith's claims, and other mycologists, Berkeley (Smith, 1876), Cornu (1881), and others, were drawn into the discussion. The outcome has been the general acceptance by modern botanists of De Bary's verdict, "not proved," regarding Smith's work. With the exception of a single paper by Smorawski (1890) no one has reopened the question during the last 25 years.

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[1] This matter was prepared for publication in 1910. Just before sending it to press Clinton's interesting announcement was received concerning the discovery of oospores of the potato fungus. It has not seemed wise to attempt any revision of this text, but instead some statements are added in a footnote at the close of this chapter, page 69.

As already stated, attention was turned to the development of methods of handling *Phytophthora infestans* in pure culture in the hope of gaining further light upon the question. While the results are not by any means conclusive they at least give encouragement for further effort. Before outlining them, a summarized account of the observations and conclusions of Smith, De Bary, and Smorawski is needed for purposes of comparison.

EARLIER INVESTIGATIONS.

In 1875 W. G. Smith published his first announcement of the discovery of what he claimed were oospores of *Phytophthora infestans*. He obtained these spores by placing potato leaves infested with this fungus in a moist chamber and allowing them to decay. Upon later examination of this decaying material he found oogonia, and antheridia and oospores with walls either smooth or spiny and he concluded that these belonged to the potato fungus. The inconclusiveness of this evidence is apparent, since decaying leaves are open to the invasion of various saprophytes. The following year Smith announced (1876) that he had been able to germinate these overwintered resting spores and from them came a germ tube on which was produced almost immediately a sporangium like that typical of *Phytophthora infestans*. These results were accepted by Vize, Broome, and Plowright (Smith, 1876), who had followed his studies.

In the meantime De Bary, under the patronage of the Royal Agricultural Society, had been employed in studies upon this same fungus, and in the journal of that society for 1876 (De Bary, 1876) he published the results which led him to discredit Smith's conclusions. Examining potato leaves, as Smith had done, which were in process of decay following the attacks of *Phytophthora infestans*, he found numerous fungus developments within them, two of which resembled Smith's so-called oospores. One of these he showed to be a saprophytic Pythium, which, because of the trouble it had given, he called

Pythium vexans; the other he identified with the *Artotrogus hydnosporus*, which Montagne had described in 1845. These spores were borne either at the tips of branches or intercalary on hyphæ showing some septation near the spore. In the tissues of potatoes penetrated by the mycelium of Phytophthora he found other bodies which suggested oogonia or oospores of the potato fungus. He interpreted these also as *Artotrogus hydnosporus*, basing his conclusion largely upon the brief description and figure published by Berkeley in 1846. Montagne described two kinds of these spores, a smooth-walled and a spiny one, but named the fungus from the spiny one. Montagne evidently regarded the two as stages of the same species, the smooth-walled one being the less mature, but De Bary was inclined to believe that while they were locally associated they were distinct. No antheridia were discovered, even after the most diligent search, and the spores were evidently to be regarded as resting spores of some unknown fungus. With regard to the relation of *Artotrogus hydnosporus* to *Phytophthora infestans*, De Bary (1876, pp. 256–257) has this to say:

> In most cases I found these bodies complete, mature, and without any distinct indication of their being attached to mycelium. It was certainly remarkable that they were often situated close to the inner surface of the cell walls in places where externally the mycelium of Phytophthora undoubtedly ran in the intercellular spaces, or even where a short branch of it penetrated the interior of the cell.

All these phenomena were reconcilable by the conjecture that the prickly bodies might perhaps be the long-sought oospores of Phytophthora; but, on the other hand, they might be of quite different origin and their bearers or producers have disappeared. A little farther along (p. 257) he says:

> There is no reason whatever to consider them as belonging to the potato fungus, unless we base it on the fact that I found them close to that fungus in the course of experiments in search of its oospores.

De Bary says, however, as to their origin: "They grow on the extremities of the branches of a mycelium, which is very like that of *Pythium vexans*." From these quotations it will be seen that *Artotrogus hydnosporus* was a puzzle to De Bary, as it had been to Montagne and Berkeley, and that, while he evidently believed that it bore no relation to *Phytophthora infestans*, he was never able to establish their distinctness.

Cornu (1881, p. 104) examined the bodies found by Smith and also the *Artotrogus hydnosporus* of Montagne Smith's oospores, he seemed inclined to believe, belonged to some species of Pythium. His studies included chemical tests on the walls of the Artotrogus spores. He concluded that nothing in the nature of these spiny-walled spores is opposed to the idea that they belong to *Phytoph-*

thora infestans, or if not to that, then to a Saprolegnia different from any with which he was familiar. He is careful, however, not to commit himself fully to the idea that they actually do belong to the Phytophthora.

Smorawski (1890) used the same methods as De Bary and Smith, simply teasing apart some of the diseased potato leaf or tuber in water. It was in a tuber that he was able to see what he interpreted as the sexual organs of the fungus. On the side branch of a conidiophore he observed two short thick branches; one of these was sack shaped and the other approached it and apparently fused with it. The only differentiation in the oospore, however, was a dark fat-containing mass at the center surrounded by a peripheral, extremely fine-grained layer of periplasm. He admits that it was impossible at any time to see the actual pressing in of the antheridial tube into the oogone. For this reason he does not deny the possibility of a parthogenetic development of the oospores.

Here, then, is the present state of the problem. All students of Phytophthora, reasoning from the behavior of the related Peronosporales, admit the possibility, if not the probability, of the occurrence of resting spores. Moreover, it is difficult to account for the occurrence and distribution of the fungus simply by means of mycelium overwintering in the tubers. Nevertheless, the claims of Smith and Smorawski, both of whom report the observance of oospores, have failed to carry conviction because of lack of accuracy in the methods followed. The most critical students have, however, admitted the possibility, remote though it be, that Montagne's *Artotrogus hydnosporus* may be the resting spore of Phytophthora.

STUDIES OF THE PROBLEM OF RESTING SPORES AT THE VERMONT STATION.

We will now review our own investigations bearing upon this question. During the winter of 1904–05 W. M. Gambell, working as a student in our laboratory with pure cultures of *Phytophthora infestans* on raw potato, observed occasional thick-walled sporelike bodies. All told he found only eight such, but since they occurred in different cultures and were quite similar they seemed significant as possibly immature resting spores. They were lying embedded in the mycelium, close to the surface, but external to the potato blocks, 22 to 23 microns in diameter, spherical, with a single smooth wall, 2¼ to 3 microns thick, which was in some nearly colorless and in others browned, the contents coarsely granular. In most cases their attachment to the mycelium could not be seen clearly, but they appeared to arise terminally on branches modified but little if any. A few more bodies essentially like these have since been found on our raw-potato cultures, but in no case have they appeared to us to be normally matured functional resting spores, although they were clearly of some unusual nature, resembling resting spores rather than the ordinary conidia of Phytophthora. Cultures were carried continuously during the next three years, at first on raw potato and potato extracts and then on the various other forms of culture media as already described. Although microscopic examinations were made of the growths on these media, nothing of further interest was seen until some potato-gelatin cultures were under examination in 1908. The growth in this gelatin medium is chiefly submerged, with a meager development of aerial branches and sporangia. Occasional brown specks, barely visible to the naked eye, were detected in the submerged mycelium. Under the microscope these specks proved to be clusters of thick-walled sporelike bodies essentially like those previously found in the raw-potato cultures, which became thus visible to the naked eye because of a brown staining of the potato gelatin in their vicinity. Particular attention was given thereafter to the growth of the fungus in this medium and, thanks to the development of the brown stain in their vicinity, these bodies, although never in great abundance, have been found frequently enough to permit careful study.

In order to prepare the mounts for microscopic examination it was necessary to melt the medium. The mycelium could then be lifted out en masse. By heating the medium in a 5 per cent solution of potassium hydroxid, the bulk of the gelatin adhering to it was removed and the material was then easily examined in glycerin and permanent mounts made in glycerin jelly. In some cases the transfer was made directly from the melted culture medium to glycerin and thence to glycerin jelly in order to avoid possible alterations by the caustic solution. The growth of the fungus in potato gelatin is never very rapid or abundant. The development of these bodies does not begin until the vegetative growth has passed its greatest vigor, which at a temperature of 20° C. has usually been some time during the second week. The brown stain is slight at first but deepens with age. Much variation in structure, grouping, and mode of development of these bodies has been observed, partly due to variations in medium. Most of these bodies have clearly been abnormal developments, or at least have failed to reach normal maturity. Indeed, we doubt if any of them are to be regarded as strictly normal. Nevertheless, it seems worth while to figure and describe the more common or striking features observed. In some cases some of these bodies were developed intercalary in a hypha, which differed from the ordinary vegetative hyphæ merely by the local enlargement and thickening of the walls (Pl. V, figs. 18 and 22). Usually, however, they were terminal and single and the hypha bearing them was enlarged and thickened for some distance backward (Pls. IV and V, figs. 1–12). Frequently the branch forked, bearing two or more of the bodies terminally

(Pl. V, figs. 11 and 12); the forking was in some repeated several times in quite regular dichotomy with the separate branches fairly long (Pl. IV, fig. 10) and in others they were less regular and short so as to bring numerous bodies into a rather dense irregular cluster (Pl. IV, fig. 1). The mycelium in old cultures of Phytophthora shows frequent septation, and this usually occurred in the vicinity of those bodies, but there seemed no point where a septum regularly occurred to delimit the enlarged sporelike end from the ordinary vegetative hypha. The wall of the enlarging end immediately adjacent to the protoplasm was sharply defined, thickened, and soon became distinctly browned, the color increasing with age. In our first series of cultures on potato gelatin this wall was bounded externally by a much thicker, clear, refractive layer (Pl. IV–V, figs. 1–16), which commonly showed some of the brown coloration, but might remain clear. At the periphery this layer was in some specimens quite smooth, with faint but distinct delimitation (Pl. V, figs. 11 and 12), the granules being apparently in part the roughened surface of this layer itself and in part the granular matter of the medium. This layer itself was interpreted to be an abnormally gelatinized surface layer of the wall, probably comparable to the exospore of the more normally developed spores to be described later.

It is to be remembered that these bodies wherever found were developed on the submerged hyphæ in the gelatinous medium and that the characters of the wall both as to coloration and thickness were doubtless in some degree modified thereby. The protoplasm was denser and more coarsely granular in these sporelike enlargements, with large vacuoles, and frequently contained relatively large oil globules. There was no differentiation of central from peripheral portions comparable to oosphere and periplasm except in one case (Pl. V, fig. 11). This bore a striking resemblance to a young oospore, but since its occurrence was exceptional and the medium so abnormal but little importance can be attached thereto. Embedded in the gelatinous outer envelope there occurred in many cases in our earlier cultures small bodies the nature or function of which was not apparent. These were lens or saucer shaped, clear, highly refractive, and often with what appeared to be a vacuole. It may be recalled that Stevens (1899, fig. 91) found somewhat similar bodies in the early stage of the developing exospore of *Albugo bliti*, but without vacuoles. This vacuolelike appearance suggests a protoplasmic nature for the bodies, but that idea does not seem tenable. Since the bodies have not been seen in our more recent cultures they must be regarded as abnormalities or possibly even as artifacts. The discovery of these sporelike structures, even though evidently abnormal, stimulated to further cultures in the hope of obtaining normally matured spores. For these, both potato gelatin and Lima-bean agar have been used. These further studies have added considerably to our knowledge of both the early stages and of the later developments of these bodies. In the very young cultures from the potato gelatin it was found that the production of typical conidia ceases soon after transfer to this medium. Instead, the bodies already described have generally soon appeared, their numbers reaching the maximum in six to eight days, and in certain cases they have developed at about the end of the second week into what appear to be mature resting spores with thick spiny walls. Even these later developments can not be accepted as entirely normal, but since they are evidently much more nearly so than the earlier ones the details will be reviewed as to their development and structure. Since no antheridia have been found and the nature of the bodies is uncertain we shall call them resting spores.

The swellings are commonly terminal, but may be intercalary; in which case they are more apt to arise at a point where the hyphæ branch. The hyphal walls immediately adjacent are swollen to several times the normal thickness and may show evidence of stratification. The walls in the early stages are also thickened and as a rule are externally smooth. A few have been observed, however, having external protuberances suggestive of the early stage of spine formation. The protoplasm extends into these protuberances so as to form a stellate mass in cross section (Pl. VI, figs. 25 and 26). At this stage the walls, which at first were colorless, were becoming light yellow and when sectioned ceased to take up analin stains, as they had done earlier. Where the protoplasmic protuberances extended, spines apparently were finally developed by the shrinking back of the material between. With approaching maturity the protoplasmic arms were withdrawn into the central mass, which thereupon became a sphere.

Similar stages were observed by De Bary in the development of the spores of *Artotrogus hydnosporus.* He records (1876, p. 257) that the external prominences of the wall were at first short and blunt, then developed into longer sharp spines, the protoplasm projecting at first into these and being later withdrawn into a globular mass inclosed in a smooth double membrane. The noteworthy difference is that our spores of this mature spiny-walled type show but a single cell membrane.

In early form and ultimate size these spores have shown considerable variation. If terminal, they were approximately spherical, but if intercalary at the forking of a hypha they may be quite irregular (Pl. VI, figs. 34, 36, 38). They are in contrast in this respect with the spherical form that is found in the loose mycelium growing on the raw potato. Doubtless this variation from the regular spherical form is simply due to the growth tension acting with the external pressure of the embedding culture medium. In diameter they have varied from 20 to 50 microns. Those that have matured sufficiently to form spiny walls are, however, more uniform, the usual sizes ranging from 21 to 33 microns. A tendency has been noted toward two extremes in size, with fewer of the intermediate sizes. No tabulated record of measurements has been kept, but we estimate that about one-half of all mature spiny-walled spores we have seen have been of the larger type, i. e., 30 to 33 microns diameter, one-fourth of the smaller type, i. e., 21 to 22 microns, and one-fourth intermediate between these two. It is probable that this difference in size is merely due to nutrition. In some cases the two sizes were borne side by side and on the same thread (Pl. VI, fig. 36). In most cases the spiny-walled spores had become detached from the threads on which they were borne and were found lying free and singly. A few have been observed attached singly to short sporophores and a few have been found clinging together in clusters of two, three, or even a much larger number (Pl. VII, figs, 39–41).

A considerable variation has been observed also in the thickness of the wall and the character of the spines. Taking the larger type (Pl. VI, figs. 33, 34, 38) as the more normal, the measurements were in general: Diameter 31 to 33 microns; thickness of wall, 3 to 4 microns; length of spines borne upon the wall, 2.5 to 4 microns. The wall does not in all cases, and perhaps in none, develop uniformly throughout. Usually three or four thinner or weaker places occur which have spines less strongly developed (Pl. VI, figs. 30–38). Perhaps these were in some cases the points of attachment to the sporogenous hyphæ. The regularity of their distribution and the ease with which they might be ruptured at this point suggested that they might function as germ pores. In some cases a short hypha extending from one or more of these suggested premature germination or else a reversal to the vegetative type of development. No further growth of such tubes has been observed by us, however. It is worth noting that De Bary (1881, pl. 1, figs. 22–26) observed something similar in his *Artotrogus hydnosporus* and that W. G. Smith in his drawing shows some similar markings. They also bear some resemblance to the papilla developed by the oogonium of certain Peronosporales, e. g., *Albugo bliti*, for the reception of the antheridial tube. Of course, the question of germination of these spores has been kept in mind but nothing has been seen beyond what is described above. Until the spores are found in larger numbers and with such uniformity in character as to give assurance of normality there is, indeed, little to encourage any attempt to germinate them. The relative sparseness of these mature forms has also made microchemical studies difficult. It has been found that the walls in the young stages readily take up gentian violet, but that as soon as they begin to turn yellow they refuse to stain. Various reagents have been tested on the mature spiny-walled spores without avail. They do not react to chlorzinc iodid, nor are they swollen or dissolved either by hot caustic potash (5 per cent solution) or by hot, strong hydrochloric or sulphuric acids. Nuclear stains were used with fair success upon the vegetative hyphæ and the early stages of these spore developments. Good stains were obtained alike whether treated in bulk or after embedding in paraffin and sectioning. Iron hæmatoxylin and Fleming's triple stain (safranin gentian violet and orange G.) were used. The vegetative hyphæ show the multinucleate condition typical of the Oomycetes. No attempt was made to differentiate the parts of the nucleus but many of them showed the nucleolus. The tendency to elongate parallel with the length of the hypha was apparent here as in the hyphæ from the potato leaf described on an earlier page (Pl. VIII, fig. 48). The sporelike bodies could be stained only in the earlier stages, i. e., until the walls began to brown.

The older stages were not very numerous and, while a few were found in the sections, these seemed to be filled with fat globules and none of them were so stained that anything could be made out as to nuclear conditions. In the younger stages, however, the bodies were multinucleate, having from 30 to 50 nuclei (Pl. VIII, figs. 42–46). These nuclei were even more elongated than those of the hyphæ, suggesting that they had been elongated with the inflowing of the protoplasm to form the body. In the later stages they were more rounded and nucleoli could be distinguished. In addition to nuclei there appeared in some of the older bodies, which were just beginning to show brown coloration of the wall, a body about four times the diameter of the nucleus. This body was fairly regular in outline and seemed filled with small dark-staining granules in some sections (Pl. VIII, figs. 42 and 46), while in others (Pl. VIII, fig. 47) it contained vacuoles. At all times, however, the staining was darker than the surrounding cytoplasm. This body may be comparable to the cœnocentrum noted by Wager (1896), Davis (1900), Stevens (1901), and others who have worked on the oospore development of this group. It allows, however, of another interpretation in view of the circumstances of its development. In size, shape, and contents it resembles the early stages of development of the oosphere in the various Peronosporales. It is true that the later stages of this body are not comparable to that, inasmuch as they then show unmistakable signs of disintegration. If we regard these bodies as oospores developed parthogenetically this central body may constitute stages in the development of the oogonium. The true nature and possible function of these bodies can at this time be nothing more than conjecture.

The preceding description has been based on the spore development obtained on potato gelatin, the medium in which they were found most abundantly. Similar bodies, including the brown spiny-walled mature spores, have been found in Lima-bean agar cultures, although only sparingly.

The most abundant development of these resting spores has been secured in submerged cultures in potato gelatin. The question has naturally arisen as to why this is so. On raw potato, where the vegetative development is most vigorous and the typical asexual spores, or conidia, are produced in greatest abundance, very few of these resting spores have been found. On Lima-bean agar there is moderate vegetative growth and sporangium production and some such resting spores, but fewer than on gelatin. Moreover, on the gelatin this type of spore formation does not occur until after the period of maximum vegetative vigor. It seems clear, therefore, that the suppression of vegetative vigor and of conidial formation is a first condition of the formation of these resting spores. The fact that they have been found only on the submerged growth in this gelatin medium further suggests that lack of oxygen may be a stimulus. Various experimental cultures were made to determine whether or not this was so. These have included attempts to stimulate their formation by keeping cultures on Lima-bean agar and potato gelatin in flasks from which the air has been partly or wholly exhausted, being replaced when wholly exhausted by carbon dioxid. No resting spores were obtained, however, by either treatment. Cultures in another series were started on the surface of either gelatin or agar tubes and then buried by pouring over them a thin layer of plain gelatin or agar solution. In most tubes no spores were developed, and where they were found in certain of the agar tubes it was not clear that the treatment was the direct cause. No further conclusions seemed justified therefore as to the relation of oxygen to their formation. It is to be recalled in this connection that wholly submerged growths have been secured on liquid potato extracts where very few conidia and no resting spores occurred.

The resemblance of these bodies to oogonia is evident, especially in the earlier stages of their development. Persistent search has, however, failed to discover any associated bodies resembling antheridia. Of course the possible relation of nutrition to antheridial development has been kept in mind. Klebs (1899, 1900) and Kauffman (1908, p. 377) have shown that the addition of certain elements to the culture medium may influence the development of antheridia in the case of Saprolegnia. As already explained, trials were made with a wide range of media but without positive results in this respect. The possibility that the development of such sexual organs might occur only when the growth of the fungus of two or more strains intermingled has been in mind from the outset of the work with these cultures, and Clinton (1905, pp. 326–328) has suggested this same idea. Two or more strains of the Phytophthora were grown intermingled upon raw-potato slices at various times in our earlier studies and a careful examination was made of the resulting mycelium, but no unusual developments occurred. After the discovery that potato gelatin was the most favorable medium for the development of these bodies more extensive trials were made with combination cultures in tubes of this medium. Nine strains of Phytophthora obtained, as already explained, from widely separated places in America and Europe were then in culture. These nine strains were paired in all the 36 possible combinations. In order to test the matter more thoroughly two cultures of each combination were started by inoculations made upon the surface of the medium, and two others where the inoculations were plunged beneath the surface so that the growths might be submerged from the outset. Thus each of the 36 pairs of strains was grown in four tubes, making a total of 144 cultures. Moreover, these cultures were repeated at four different times. Examinations of these mixed cultures revealed no unusual developments, either in kind or number of the bodies, as compared with the cultures of single strains, which were always made as controls. It is possible that further trials with other media or different environmental conditions might lead to other results. Under the circumstances, however, the only conclusion which seems justifiable is that there is no evidence of sexual differentiation of these Phytophthora strains and that these bodies are produced asexually.

Of course it is possible that resting spores of this sort, produced under the abnormal conditions of our culture tubes, may have no counterpart in nature. Brefeld (1873) and Klebs (1896) have both recorded evidence of the abnormalities which may result in fungus cultures under abnormal cultural conditions. Certainly no practical conclusions can be drawn from these observations, except as they may be supported by evidence obtained from more natural growths. Diligent and repeated searches upon pure cultures on raw potato in tubes, as previously explained, have led to the finding of but very few of these bodies, and these few were smooth walled, apparently immature, and of somewhat doubtful character. We have no encouragement, therefore, for the belief that Phytophthora forms resting spores with any degree of regularity or frequency in the tissues of the potato tuber.

Reference has already been made to the fact that Smith (1876) and others have found resting spores in decayed potato leaves following the invasion of Phytophthora, and these have been doubtfully regarded as belonging to this fungus. These observations have been repeated in our laboratory by taking leaves which were thoroughly invaded by Phytophthora and placing them in a glass dish lined with moist filter paper. Of course such leaves are promptly rotted with the development of saprophytic bacteria and fungi. Examination after a couple of weeks has generally shown numerous resting spores (Pl. VI, fig. 28) corresponding in a general way with those described by others and somewhat similar to some of those found in our culture tubes. The origin of these spores has not as yet been traced to our satisfaction, nor have we been able to germinate them. In view of the historical evidence, and the abundant development observed of secondary saprophytes, the presumption must remain that these resting spores occurring in decaying potato leaves are of Pythium or some related saprophytic species. But the matter merits renewed attention.

The only evidence here presented which is of much importance is based upon the cultural work, the validity of which rests upon the purity of our cultures. A summary of the reasons for our confidence in their purity is therefore here given. These spores have been found in nine different strains of Phytophthora, which were all that were being carried in our laboratory at the time of these later studies. All but one of these nine strains were obtained from diseased potato tubers and isolated in our laboratory; the one exception was sent us by Dr. Clinton from Connecticut. These tubers were obtained from widely different sources including Vermont, Maine, Connecticut, Pennsylvania, England, Ireland, and Germany. The strains were isolated at different times and by three different persons. Some difficulty was usually experienced at the outset in eliminating bacteria from these cultures, but no trouble was experienced with fungi. These nine strains were carried continuously in culture for over three years without anything occurring to throw suspicion on their purity. Repeated transfers from these cultures to ordinary bacteriological media, nutrient broths, agar, and gelatin have uniformly failed to secure growth, as likewise have transfers to cooked potato and other vegetables. This fact seems to rule out the occurrence of any ordinary type of saprophyte. Inoculation experiments at various times have been made from these cultures to potato leaves upon greenhouse plants, and characteristic infections have always been promptly obtained showing that the Phytophthora persists with virulence unimpaired. It is not believed possible that any admixture of saprophytic growth could have entered all cultures alike, much less persist without detection. The only suggestion that seems worthy of further consideration is that these resting spores might belong to a species parasitic upon Phytophthora as Piptocephalis is upon certain molds. De Bary, indeed, suggests (1881) such relation as possible between *Artotrogus hydnosporus* and *Pythium debaryanum.* It would seem to us almost impossible, however, that such a condition should occur in all nine cultures alike and persist without detection during so long a period and under such varied cultural conditions.[1]

DISEASE RESISTANCE OF POTATOES.

A historical review and summary of the main facts as to the disease resistance of potatoes were given by the senior writer in an earlier publication (Jones, 1905). As there pointed out, differences were observed in the liability of potato varieties to the ravages of blight and rot almost from the appearance of the disease in Europe. The necessity for systematic attempts for varietal improvement in this respect was clearly recognized in England over 30 years ago. The English Parliament was asked to give direct aid to this project in 1880. American varieties were sought as a basis for improvement of the English strains and hybridizing was practiced. The best production of the early English breeders was Magnum Bonum, the result of a cross of the American Early Rose with the English Victoria in 1876. The superior disease-resisting qualities of this cross not only made it the standard main-crop variety, but stimulated further attempts at the production of disease-resisting varieties. Indeed, disease resistance has since been a clearly recognized aim of all British potato specialists. Attention has more recently been turned toward the same goal in Germany and elsewhere on the continent of Europe. The senior writer, in 1904, as special agent of the Department of Agriculture, obtained a collection of the most promising European varieties for trial in America, together with a representative series of American varieties. These varieties have since been tried in the field at the Vermont experiment station by William Stuart, and elsewhere under the supervision of W. A. Orton, of the Department of Agriculture. Stuart's results, which have received preliminary consideration in a Vermont station bulletin (1906) and which later will be referred to more in detail, showed certain German, English-Scotch, and Dutch varieties to have a much higher degree of disease resistance than the standard American varieties.

While this field work has been in progress efforts in the laboratory studies have been directed along two lines: (1) To test, and if possible perfect, methods of determining relative disease resistance by inoculation with Phytophthora; (2) to learn any facts concerning the location and possible nature of the Phytophthora-resistant qualities.

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[1] After the above matter was prepared for publication, Dr. G. P. Clinton's very interesting publications were received reporting the discovery of oospores of the potato fungus (Science, n. s., vol. 33, May 12, 1911, p. 744, and Report of the Connecticut Agricultural Experiment Station, 1909–10, distributed June, 1911, p. 753). Time has not permitted repetition in our laboratory of his cultural studies. The reading of his report is recommended, and also trial of the new medium to which he attributes the development of antheridia, viz, 50 grams ground oats (grain), 350 c. c. water (steamed), 10 grams agar (steamed), water to make 500 c. c. (autoclave 15 minutes at 7 to 10 pounds pressure).

The practical importance of both of these matters should be clear. All the previous trials to determine relative disease resistance have been based on field observations as to the occurrence of blight and rot following natural infection. The tardiness and uncertainty of this method are shown by Stuart's experience, since in his trials covering the six years 1905 to 1910 he has had only one year, 1905, when there was such a uniform and abundant development of the fungus upon his fields as is necessary to furnish reliable data. Moreover, even when the required development does occur, much allowance must be made for minor variations in atmospheric and soil conditions, and data so secured, especially as to rot, are not altogether satisfactory.

On the other hand, the potato specialist who is endeavoring by breeding or selection to develop more highly resistant varieties has urgent need for more information as to what constitutes disease resistance. Is it a matter of habit of growth, or epidermal texture, or other characters, or does it reside in the internal tissues and, if so, is it due to the presence of some recognizable chemical compound? With these questions in mind, inoculation studies were made on both potato leaves and tubers.

STUDIES OF PHYTOPHTHORA RESISTANCE AS SHOWN BY POTATO LEAVES.

Frequent trials have shown that leaf infections are easily obtained by applying Phytophthora spores to moistened potato leaves, provided moisture conditions are properly maintained. The main object in the present experiments with the foliage infection was to learn whether there would be a noticeable difference in either the percentage of infection or the rate of spread through the leaf tissues, following artificial infection of varieties reputed to be disease resistant, as compared with those considered more susceptible. Of course it was not practicable to carry on such a trial as this in the main variety field, since there would be too much danger from the proximity of so many susceptible varieties.

The German variety Irene, the English variety Holborn Abundance, and the American variety Ionia Seedling were selected as the most promising ones available in the smaller garden where the work was undertaken. Stuart's earlier experiments (1906, p. 110) had shown these varieties to have considerable difference in foliage resistance to Phytophthora. No late-blight was present on the plants when the work was undertaken, nor did it develop elsewhere in the field while the experiment was under way. Twenty leaflets occurring on three hills of each of these varieties were inoculated August 1 with Phytophthora. The weather being dry and warm, precautions were necessary to insure moisture conditions favorable for the development of the fungus. This need was successfully met by wetting down the plants and adjacent soil thoroughly, making the inoculations in the late afternoon, and covering each plant with a barrel during the first night. Fresh spores of Phytophthora from potato leaves were brought from another field which was blighting as a result of earlier artificial inoculation. These spores were applied in a drop of water near the end of the leaflet under trial. The inoculated leaflets were tagged and numbered and the outline of each traced on thin semitransparent paper, to be used as a record sheet for following the progress of the disease. On August 5 the first sign of dying tissue was evident and its outline was traced with pencil in the corresponding leaf outline (fig. 8). Two days later, when the spots had increased, new tracings were added, and this process was repeated on August 9, 12, 14, 16, 17, and 19. Well-marked differences were noted, both in number of resulting infections and in rapidity of development. Two of the leaves were lost from the Irene plants by accident.

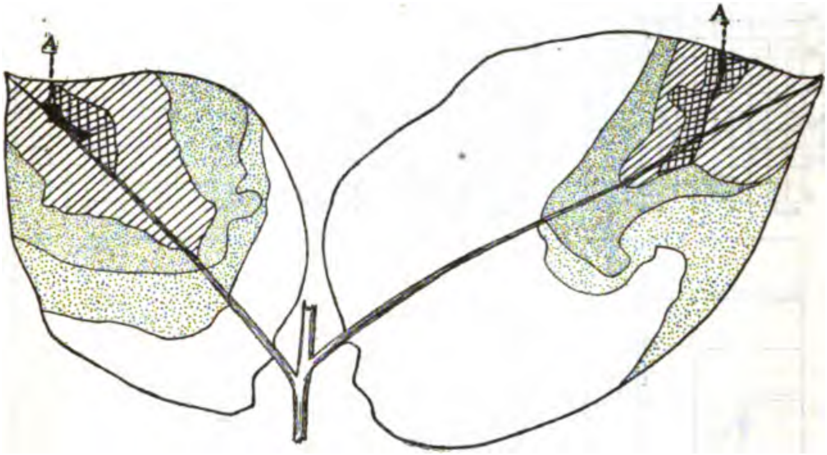

FIG. 8.—Diagrammatic representation of the rate of progress of *Phytophthora infestans* in two leaflets of the Ionia Seedling potato from the fourth to the eleventh day after infection during dry, warm weather, which was unfavorable to the fungus; the progress would have been much more rapid in moist weather. The black areas (*A*, *A*) represent the amount of dead tissue on the fourth day. The subsequent enlargements for the sixth, eighth, tenth, and twelfth days are indicated by the various shadings.

Table X shows the percentage of infection on the remaining leaves.

TABLE X.—*Percentage of leaf infection shown by different varieties of potatoes.*

Varieties tested.	Number of leaves—		Percentage of infection.	Percentage of total leaf area found diseased on successive days after infection.				
	Inoculated.	Infected.		4 days.	6 days.	8 days.	10 days.	12 days.
Ionia Seedling	20	17	85	7.14	8.11	24.67	52.12	58.98
Holborn Abundance	20	11	55	.29	5.78	21.98	22.93	40.98
Irene	18	7	39	3.00	5.75	17.25	18.00	18.00

Had the weather been more favorable the progress of the fungus would have been more rapid, of course; but the slower progress was more favorable for our purposes, viz, the observation of the comparative progress.

These results show a well-marked resistance to fungus invasion on the part of Irene, with less by Holborn Abundance and least by Ionia Seedling. Moreover, these differences correspond very well with those recorded by Stuart (1905, p. 111) of the percentage of foliage he observed to be affected by late-blight in his field trials as a result of natural infection. In his field, when Ionia Seedling showed 20 per cent of foliage affected, Holborn Abundance showed 15 per cent and Irene only 5 per cent. Still more marked was the difference in the rate of progress of the disease, which was considerably the more rapid on Ionia Seedling, less on Holborn Abundance, and least on Irene. In order to compute these differences with more exactness the planimeter was used for making exact measurements of the leaf outlines and of the successive increases in blighted area. These results are also shown in Table X.

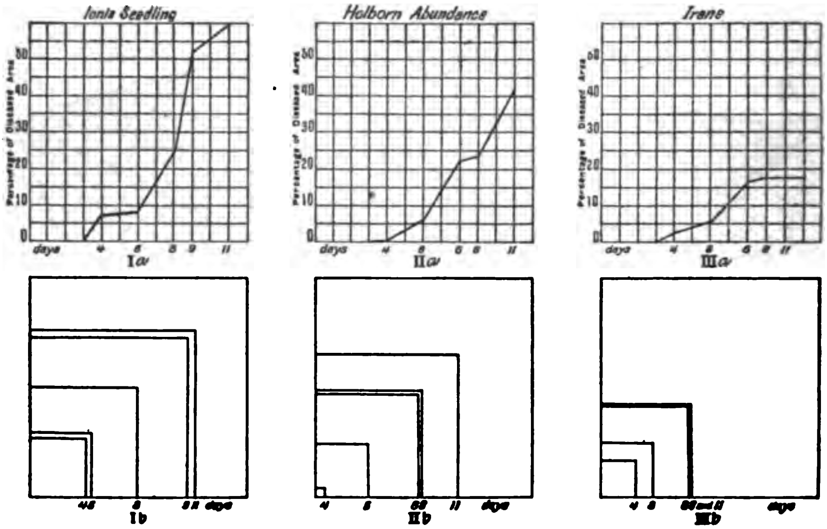

FIG. 9.—Graphic representation of the relative rates of progress of *Phytophthora infestans* following artificial infection of the leaves of three varieties of potatoes, the American variety Ionia Seedling (I*a*, I*b*) being highly susceptible, the British variety Holborn Abundance (II*a*, II*b*) moderately so, and the German variety Irene (III*a*, III*b*) highly resistant. In the upper diagrams each unit on the base line represents one day and each vertical unit 5 per cent of the area of leaf. In the lower diagrams the largest square represents the total leaf area and the smaller inclosed squares show the percentages of disease on the fourth, sixth, eighth, ninth, and eleventh successive days.

A second series of inoculations was made later in the same month. These inoculations showed essentially the same differences, but the progress of the disease was slower; and this was true of a third series run in September, owing partly to unfavorably dry weather the latter part of the summer.

The graphic representation of the relative rates of progress of the blight shown in figure 9 is based on the figures in the first series. The results from the second series are also plotted for comparison (fig. 10). As already noted, the developments here were slower, but the relative rates were quite similar. In the first set of diagrams each unit in the base line represents one day and each unit in the vertical 5 per cent of diseased area. In the second set the largest square represents the total leaf area and the smaller inclosed squares represent the percentages of diseased areas on the successive days of observation.

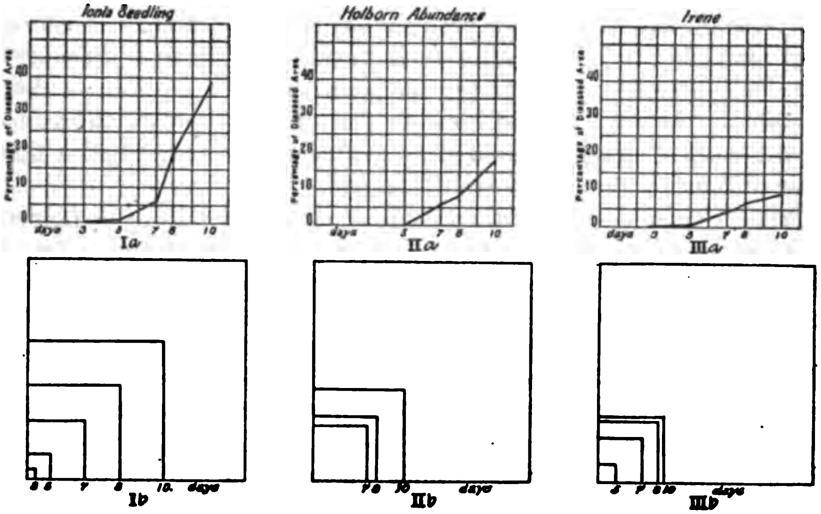

FIG. 10.—Graphic representation of the relative rates of progress of *Phytophthora infestans* following artificial infection upon potato leaves of the same varieties shown in figure 9, in a second series of experiments, the American variety, Ionia Seedling (*Ia*, *Ib*) being highly susceptible, the British Holborn Abundance (*IIa*, *IIb*) moderately so, and the German variety Irene (*IIIa*, *IIIb*) highly resistant. In the upper diagrams each unit on the base line represents one day and each vertical unit 5 per cent of the area of leaf. In the lower diagrams the largest square represents the total leaf area and the smaller inclosed squares show the percentages of disease on the successive days recorded on the margins. Comparison with the diagrams in figure 9 shows similar differences, although the rates of progress were slower.

Conclusions.—While these trials were too limited to justify broad generalizations, they seem clearly to show two things concerning foliage resistance: (1) That when these different potato varieties were exposed to like opportunities for foliage infection a difference appeared in the actual number of infections that resulted, indicating variations in relative Phytophthora resistance; (2) that following such infection a still more marked difference was shown in the corresponding rate of leaf-tissue destruction in the resistant as compared with the susceptible varieties. This second observation clearly indicates that the disease-resisting characteristic is largely, if not wholly, inherent within the interior tissue or mesophyll of the leaf rather than in the epidermis.

STUDIES OF PHYTOPHTHORA RESISTANCE AS SHOWN BY POTATO TUBERS.

All previous studies have been based on field observations of the difference in the amount of rot following natural infection while the tubers were lying in the soil. From the inception of our work in cultivating the fungus upon the sterile blocks cut from the tubers variations were observed in the amount of growth obtained. As the work progressed systematic trials were undertaken to see how wide and constant this variation is between varieties and to perfect laboratory methods for determining such variation. At first difficulties were encountered in so preparing the potato blocks as to insure a close enough uniformity in conditions to permit of reliable conclusions. As the work progressed laboratory methods were so perfected that these difficulties were fairly well overcome.

Trials were made to obtain information on the following points: Is it practicable by the laboratory method to determine the relative disease resistance of the tubers of different varieties? Is such disease-resistant quality localized in the tuber—e. g., is it in the superficial as compared with deeper portions of the flesh? What is the basis of such disease resistance? Is it intimately associated with or inherent in the living protoplasm or is it due to some chemical content separable from the living tissue?

The tubers used for determining this point were selected, with one exception, from those grown on the trial grounds of the Horticultural Department of the Vermont experiment station at Burlington in 1909, under the direction of William Stuart, horticulturist. The single exception was the Irish Cobbler, which was grown in another trial field at St. Albans, Vt. The field where the others were grown is a uniform sandy loam which had received annually for the preceding four years 800 pounds of concentrated fertilizer per acre (200 pounds cottonseed meal, 400 pounds acid phosphate, 133 pounds muriate of potash, 67 pounds nitrate of soda). The seed tubers were from the strains grown on the trial grounds at this station under uniform conditions for four seasons previous, and the uniformity in these as well as in soil conditions leads us to believe that the variations which might result from lack of uniformity in seed or soil were largely eliminated.

RELATIVE RESISTANCE SHOWN BY DIFFERENT VARIETIES.

For these trials uniformity in laboratory method and material was the first consideration. The following details are therefore given. They will be made clearer by reference to Plates IX and X.

Uniform test tubes (13 by 1.5 cm.) were used, and 1 cubic centimeter of distilled water was placed in each together with a small wad of absorbent cotton, barely sufficient in size to hold this water. The tubes were then tightly plugged with cotton and autoclaved for 15 minutes at 5 pounds pressure. The tubes were then ready to receive for trial the sterile potato blocks which were prepared as follows: Sound, smooth tubers of medium or large size were washed and immersed for five minutes in 0.1 per cent mercuric-chlorid solution. The problem now was to cut sterile blocks of uniform size from the interior of the tuber and insert one such freshly cut, uncontaminated block into each tube. The desired result was accomplished satisfactorily after some practice by working under a hood, holding the tuber with a sterile fork and cutting it with heat-sterilized, but cool, knives. Precautions must be taken not only against germ contaminations but also against carrying any mercuric chlorid from the surface layer to the interior flesh. For these reasons the peel was first removed by a series of cuts parallel with the surface and then a thin second layer of the flesh removed before cutting out the trial blocks. In this way the outer flesh to a depth of 0.5 to 1 centimeter was discarded. If any discoloration or other evidence of unsoundness was discovered in the interior flesh the tuber was, of course, rejected. The interior flesh was then cut lengthwise of the tuber into blocks as uniform in size as practicable (about 1 by 1 by 4 cm.), each block as cut being promptly transferred to its tube. It is desirable to have the block as large as will slip easily into the tube, so as to insure uniformity in moisture conditions. A good-sized tuber will give 15 to 18 such blocks. The tubes so prepared were kept at room temperature 24 hours before inoculating, and those which showed signs of contamination were discarded. After perfecting the methods described but little trouble was experienced from contamination. To further guard against irregularities resulting from contamination as well as from minor variations in size of block, moisture relations, success in inoculation, etc., 15 blocks of each variety were used in each trial.

The inoculations in each series were made with care from pure cultures of Phytophthora grown on Lima-bean agar for 10 to 15 days to insure uniformity. It was found that uniformity in inoculation was best attained by using a stiff platinum-iridium needle with an L-shaped bend at the tip and transferring a small bit of the agar along with the fungus. It is, of course, important to have the piece transferred as uniform in size as practicable; ours were about 3 millimeters in diameter. Uniform growth was further insured by placing this piece of agar on the side of the potato block about 1 centimeter from the top and scratching it into the surface sufficiently to insure close adhesion (Pls. IX and X).

It was soon learned that the standard American variety Green Mountain is one of the most favorable for the development of the fungus (Pl. IX), while the German variety Professor Wohltmann is one of the more resistant. These two varieties were therefore taken as standards with which all other varieties were thereafter compared. It was found that about 200 tubes were as many as could be prepared and examined in one series. Fourteen varieties, 15 tubes each, were therefore started in each series, including Green Mountain, Professor Wohltmann, and 12 others. After inoculation the cultures were held in a moist incubator at 15° to 16° C. A fair growth was thus obtained by the sixth day and the maximum, on the more susceptible varieties like Green Mountain, was reached in 10 days. On the seventh day the cultures were carefully examined and the 10 tubes of each variety showing the best development were selected for further comparison with the two control varieties and with each other.

Another comparative examination was made on the tenth day, and in doubtful cases a third examination was made on the thirteenth day.

The photographs reproduced in Plates IX and X will give some notion of the differences in growth shown on certain of these varieties; the differences shown are much less marked than in the original cultures, owing to the impossibility of representing the details of the fungous mycelium, especially when photographed through the curved walls of the culture tube.

In order to establish standards for comparison, judgment was recorded on a percentage basis, the most vigorous growth, which entirely covered the surface of the potato block, being rated at 100 per cent and lesser growths in proportion. On this basis the Green Mountain was rated pretty uniformly at 95 per cent, whereas the weak growth on the control variety, Professor Wohltmann, was rated at about 10 per cent. Two persons recorded their judgment independently upon the relative developments, and three or more judges passed upon many of them. The general reliability of the method is attested by the fact that difference in these judgments was rarely noted as to the sequence in which the various varieties under inspection were to be placed; usually the percentage ratings given by the different judges were within 5 to 15 per cent of each other, and frequently they were identical.

After carrying through the first series of tests a second series was run, involving all varieties, and where the results obtained in the second series differed much from those of the first, still further tests were made. Working in this way it required the preparation and examination of some 3,000 cultures to reach conclusions as to the rating of the 76 varieties reported upon in Table XI. The final percentage rating given in the table is the average of all ratings made upon the mature (10-day) cultures of that variety in the two or more series.

TABLE XI.—*Relative percentage of growth of Phytophthora in pure tube cultures on potato tubers of different varieties, representing five different countries.*

No.	Name of variety.	Source.[1]	Growth.	No.	Name of variety.	Source.[1]	Growth.
			Per cent.				*Per cent.*
1	Royal Kidney	Britain	1	39	Topaz	Germany	50
2	Gastold	Germany	2	40	Enormous	America	50
3	Geheimrat Thiel	do	4	41	Max Eyth	Germany	50
4	Evergood	Britain	6	42	Pearl of Carmen Valley	America	55
5	Up-to-Date	do	7	43	Million Dollar	do	55
6	Quarantaine de la Halle	France	7	44	Silesia	Germany	60
7	Eldorado	Britain	8	45	Apollo	do	60
8	Goodfellow	do	8	46	Money Maker	Britain	70
9	Magnum Bonum	do	9	47	Ninety Fold	do	70
10	Sir John Llewellyn	do	10	48	Burbank	America	70
11	Langworthy	do	10	49	Dabersche	Germany	70
12	Professor Wohltmann	Germany	11	50	Manistee	America	70
13	Irene	do	11	51	Twentieth Century	do	75
14	Radium	Britain	12	52	Gem of Aroostook	do	78
15	Malador	Holland	12	53	Rural Blush	do	78
16	Alexander's No. 1 Red	America	13	54	Dakota Red	do	80
17	Eureka	Holland	14	55	American Wonder	do	80
18	Landskroon	do	16	56	Northern Star	do	80
19	Sophie	Germany	20	57	Early Rose	do	83
20	Professor Maerker	do	20	58	June	do	85
21	Duke of York	Britain	23	59	Irish Cobbler	do	85
22	British Queen	do	25	60	Vermont Gold Coin	do	86
23	Gelbfleischige Speise	Germany	25	61	Delaware	do	87
24	Daisy	Holland	25	62	President Kruger	Germany	87
25	Jersey Peachblow	America	25	63	Beauty of Hebron	America	87
26	Richter's Imperator	Germany	25	64	Star of the East	do	87
27	Manly	America	28	65	Sir Walter Raleigh	do	90
28	Fuerst Bismarck	Germany	28	66	Rural New Yorker No. 2	do	60
29	Charles Fidler	Britain	30	67	Quick Lunch	do	90
30	Boncza	Germany	30	68	Late Blightless	do	90
31	Cambridge Russet	America	35	69	Belle de Fontenay	France	90
32	Leo	Germany	40	70	Smith's Blight proof	America	91
33	Windsor Castle	Britain	40	71	Green Mountain jr	do	91
34	Eigenheimer	Germany	45	72	Harris Snowball	do	93
35	Holborn Abundance	Britain	45	73	Norcross	do	94
36	Keeper	America	45	74	Early Excelsior	do	94
37	Factor	Britain	47	75	Quick Crop	do	94
38	Mohort	Germany	50	76	Green Mountain	do	95

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[1] The original source of the variety is stated, viz, whether its origin is Great Britain (Britain), Germany, France, Holland, or America. Tubers were selected from strains which had been grown under uniform conditions upon a sandy loam on the trial grounds of Prof. William Stuart, horticulturist of the Vermont Agricultural Experiment Station. Moreover, most of them had been similarly grown for four seasons previously. All of the foreign strains—British, German, French, and Dutch—were obtained from reliable parties in their respective European countries in 1904 and there selected because of their reputed disease-resistant qualities. Most of the American varieties were assembled that same year as including the most promising American varieties with respect to disease resistance. For further details as to the assembling of these, their exact source, and their reputed disease-resistant qualities, see Jones, 1905, pp. 28–39; Stuart, 1906, pp. 134–136.

Inasmuch as the basis of the percentage rating was established somewhat arbitrarily, the chief significance of the table lies in the sequence of the varieties. Further trials, especially if made with tubers from different sources, might lead to minor changes in their sequence. It would perhaps give less opportunity for misinterpretation and serve most practical results quite as well to merely divide the potatoes into five groups marked by the 20, 40, 60, and 80 per cent ratings given above.

Group 1. *Highly resistant varieties:* Royal Kidney, Gastold, Geheimrat Thiel, Evergood, Up-to-Date, Quarantaine de la Halle, Eldorado, Goodfellow, Magnum Bonum, Sir John Llewellyn, Langworthy, Professor Wohltmann, Irene, Radium, Malador, Alexander's No. 1 Red, Eureka, Landskroon, Sophie, Professor Maerker (9 British, 7 German, 2 Dutch, 1 French, 1 American).

Group 2. *Moderately resistant:* Duke of York, British Queen, Gelbfleischige Speise, Daisy, Jersey Peachblow, Richter's Imperator, Manly, Fuerst Bismarck, Charles Fidler, Boncza, Cambridge Russet, Leo, Windsor Castle (3 British, 6 German, 1 Dutch, 3 American).

Group 3. *Intermediate:* Eigenheimer, Holborn Abundance, Keeper, Factor, Mohort, Topaz, Enormous, Max Eyth, Pearl of Carmen Valley, Million Dollar, Silesia, Apollo (2 British, 6 German, 4 American).

Group 4. *Moderately susceptible:* Money Maker, Ninety Fold, Burbank, Daberscne, Manistee, Twentieth Century, Gem of Aroostook, Rural Blush, Dakota Red, American Wonder, Northern Star (2 British, 1 German, 8 American).

Group 5. *Very susceptible:* Early Rose, June, Irish Cobbler, Vermont Gold Coin, Delaware, President Kruger, Beauty of Hebron, Star of the East, Sir Walter Raleigh, Rural New Yorker No. 2, Quick Lunch, Late Blightless, Belle de Fontenay, Smith's Blightproof, Green Mountain Jr., Harris Snowball, Norcross, Early Excelsior. Quick Crop, Green Mountain (1 German, 1 French, 18 American).

The first group is the one in which the minor differences are of chief practical interest. It is, therefore, of importance to note that it was in this one that the ratings were most easily and confidently decided and in which we believe they have the most permanent value.

The remarkably high degree of disease resistance which occurs in certain of the European varieties as contrasted with the American varieties is clearly shown in Table XI. It is to be remembered that these European varieties were selected by the senior writer in 1904 for reputed disease-resistance, and their relative merits in this respect were demonstrated soon thereafter by Stuart (1906). Stuart's results were derived from field trials using these same varieties and the same strains in practically all cases which we have since been using for these laboratory trials. It is of especial interest, therefore, to compare his results with those recorded above. These are entered in Table XII for all the varieties which were included in both series of trials. Stuart's records show the amount of rot developed in the field under natural conditions of infection associated with an epidemic of late-blight of the foliage. His trials were conducted on two fields, (A) a sandy-loam soil and (B) a clay loam. There was much rain in the autumn, when Phytophthora was prevalent, and as a result there was much more rot on the clay. The first figure column in the table shows the percentage rating given in our trials, the second column the percentage of rot which occurred in Stuart's trial on the sandy field, and the third column the percentage of rot in Stuart's clay field.

TABLE XII.—*Development of Phytophthora in laboratory trials compared with the percentage of rot observed in the field on different varieties of potatoes.*

Variety.	Laboratory trial.	Field trial.		Variety.	Laboratory trial.	Field trial.	
		Sand.	Clay.			Sand.	Clay.
Royal Kidney	1	2	12	Eigenheimer	45	1	21
Gastold	2	1	9	Holborn Abundance	45	10	38
Geheimrat Thiel	4	4	18	Keeper	45	2	12
Evergood	6	1	3	Factor	47	17	60
Up-to-Date	7	6	38	Mohort	50	0	4
Quarantaine de la Halle	7	8	83	Topaz	50	1	......
Eldorado	8	1	0	Enormous	50	23	68
Goodfellow	8	1	3	Max Eyth	50	2	20
Magnum Bonum	9	1	16	Million Dollar	55	16	42
Sir John Llewellyn	10	0	72	Silesia	60	1	10
Langworthy	10	1	19	Apollo	60	0	5
Professor Wohltmann	11	1	1	Money Maker	70	5	......
Irene	11	1	0	Daberache	70	1	49
Radium	12	5	......	Gem of Aroostook	78	16	77
Malador	12	1	9	Rural Blush	78	5	56
Alexander's No. 1 Red	13	1	1	Dakota Red	80	4	40
Eureka	14	1	5	American Wonder	80	2	42
Landskroon	16	2	11	Northern Star	80	2	27
Sophie	20	2	9	Early Rose	83	19	89
Professor Maerker	20	4	8	June	85	......	30
Duke of York	23	4	78	Vermont Gold Coin	86	22	74
British Queen	25	5	33	Delaware	87	18	73
Gelbfleischige Speise	25	1	27	Star of the East	87	27	55
Daisy	25	0	9	Sir Walter Faleigh	90	21	62
Richter's Imperator	25	4	29	Rural New Yorker No. 2	90	6	45
Fuerst Bismarck	28	1	4	Quick Lunch	90	9	......
Charles Fidler	30	0	......	Late Blightless	90	7	34
Boncza	30	2	11	Belle de Fontenay	90	3	49
Cambridge Russet	35	2	60	Harris Snowball	93	9	73
Leo	40	0	18	Norcross	94	29	68
Windsor Castle	40	3	80	Green Mountain	95	21	80

Of course, the basis for these figures is so entirely different that any detailed numerical comparison is idle. The relative rating in each trial is the thing of prime significance. As already stated, the chief interest centers upon the detection of varieties of especial disease-resistant quality. Stuart's trials on the sandy field showed extreme percentages of rot, ranging from zero to about 30. In the clay field the extreme reached 100 per cent. If we are to attempt, somewhat arbitrarily it is true, to make five groups upon the basis of Stuart's trials, as was done upon the basis of our trials, it would seem that all varieties showing less than 10 per cent of rot in the sandy field might properly be rated, so far as that evidence goes, as highly disease resistant, and those showing less than 20 per cent rot in the clay fields should be thus rated. Scanning the figures given for the 20 varieties rated on the basis of our tests as in the highly disease-resistant class, it will be seen that all but two, or perhaps three, are put in the same group by Stuart's figures. The exceptions are Up-to-Date, which according to Stuart's figures would go into the second group, and Quarantaine de la Halle, which showed a still higher percentage of rot and would be by these figures rated as a susceptible variety. The Sir John Llewellyn showed considerable rot on the clay soil but none whatever on the sandy soil. Both the Up-to-Date and the Sir John Llewellyn varieties are reported as highly disease resistant in Great Britain.

So far as can be judged from the data at hand, therefore, this laboratory method seems reliable as well as expeditious for the determination of the Phytophthora-resistant qualities of the tubers. It possesses certain advantages which are at once obvious over the method of field trial, depending as that does on the chances of natural infection. The natural infection of the tubers in the field is conditioned in the first place upon the development of the fungus on the foliage. This is by no means uniform even on the same variety and varies widely on different varieties. Moreover, according to Stuart's observations (1906, p. 116) foliage resistance is not always correlated with tuber resistance. Thus the American variety Rustproof showed a high degree of foliage resistance, but the tubers are especially subject to rot. Apollo, a German variety, showed only 5 per cent of leaf infection in Stuart's trials, as compared with 95 per cent on the English variety Royal Kidney. Our laboratory tests show Royal Kidney tubers to be much more resistant than Apollo. Stuart's field trials on the other hand show more rot in Royal Kidney than in Apollo. It seems reasonable to believe that this variation in results may have been due merely to the difference in natural infection resulting from greater development of the fungus on the Royal Kidney foliage. Minor variations in character of soil and surface drainage may have a marked effect on the percentage of rot, as may also the depth to which the tubers are buried. Moreover, if one depends wholly on field trials he must often wait several years before climatic conditions are such as to bring on the sudden and uniform development of the fungus which is necessary to furnish satisfactory data. On the other hand, by the laboratory method the relative Phytophthora resistance of a given series of tubers can be determined in a short time quite independently of the relation to foliage, the changes of climate, or the variations in soil.

The data already given, comparing the resistance of the several varieties to Phytophthora in the laboratory tests with the results in the field, have been arranged by Mr. J. B. Norton in the form of a table showing correlation for the sandy field and for the clay field.

TABLE XIII.—*Correlation between percentage of infection of tubers of potatoes with Phytophthora in laboratory tests and percentage of rot in tubers of same varieties grown on sandy soil or on clay soil.*

Percentage of rot of tubers grown on—	Number of varieties showing given percentages of infection in laboratory tests.										Frequency.	Departure from mean.
	0 to 10	11 to 20	21 to 30	31 to 40	41 to 50	51 to 60	61 to 70	71 to 80	81 to 90	91 to 100		
Sandy soil:												
0 to 3	8	7	5	3	5	2	1	2	1	......	34	− 4.5
4 to 6	3	2	3	......	......	......	1	2	1	......	12	− 1.5
7 to 9	1	......	......	......	......	......	......	......	2	1	4	+ 1.5
10 to 12	......	......	......	......	1	......	......	......	......	......	1	+ 4.5
13 to 15	......	......	......	......	......	......	......	......	......	......	......	+ 7.5
16 to 18	......	......	......	......	1	......	......	1	1	1	4	+10.5
19 to 21	......	......	......	......	......	1	......	......	2	......	3	+13.5
22 to 24	......	......	......	......	1	......	......	......	1	......	2	+16.5
25 to 27	......	......	......	......	......	......	......	......	1	......	1	+19.5
28 to 30	......	......	......	......	......	......	......	......	......	1	1	+22.5
Frequency	12	9	8	3	8	3	2	5	9	3	62	
Departure from mean	−33.4	−23.4	−13.4	−3.4	+6.6	+16.6	+26.6	+36.6	+46.6	+56.6	......	
Clay soil:												
0 to 10	4	7	2	......	1	2	......	......	......	......	16	−30
11 to 20	4	1	1	1	2	......	......	......	......	......	9	−20
21 to 30	......	......	2	1	1	......	......	1	1	......	6	−10
31 to 40	1	......	1	......	1	......	......	1	1	......	5	0
41 to 50	......	......	......	......	......	1	1	1	2	......	5	+10
51 to 60	......	......	......	1	1	......	......	1	1	......	4	+20
61 to 70	......	......	......	......	1	......	......	......	1	1	3	+30
71 to 80	1	......	1	......	......	......	......	1	2	2	7	+40
81 to 90	1	......	......	......	......	......	......	......	1	......	2	+50
Frequency	11	8	7	3	7	3	1	5	9	3	57	
Departure from mean	−40	−30	−20	−10	0	+10	+20	+30	+40	+50	......	

Coefficient of correlation between laboratory tests and tests on sandy field, 0.5936±0.055; between laboratory tests and tests on clay field, 0.584±0.059.

Mr. Norton appends a paragraph of explanation, as follows:

In attempting a statistical study of the results presented in Table XIII it becomes at once apparent that the varieties used in the test were not selected at random in regard to their resistance to the rot. The European varieties, in particular, were the most rot resistant that could be found. In neither of the field trials nor in the laboratory test do the frequency distributions suggest a normal probability curve, but this fact does not seriously affect the results. The important fact shown in the table is that in very few cases the rot in the field trials exceeds in a marked degree the susceptibility indicated by the laboratory test. This fact makes the reliability of the laboratory test much higher than the correlation indicates. The tubers used in the field trials in many cases failed to rot where the laboratory test shows susceptibility. These cases, while weakening the coefficient of correlation, do not affect the value of the method, since in most cases this failure to rot is probably due to environmental conditions preventing infection in the field trials.

NATURE AND DISTRIBUTION OF THE PHYTOPHTHORA-RESISTING PROPERTY.

Early in the conduct of these studies the question arose as to the location or distribution of the disease-resistant quality and its possible nature. Various lines of study with both foliage and tubers were undertaken to obtain data as to these matters. So far as these studies relate to the fundamental question of the nature of the disease resistance the results are largely negative, but certain facts were learned as to its distribution.

The trials already discussed show that with both organs the fungus resistance is not merely due to difference in epidermal or superficial tissues. Thus in Irene the progress of the fungus through the mesophyll of the leaf was much slower than with Ionia Seedling, showing that there is something in the interior tissues of Irene which furnishes a Phytophthora-resistant character quite apart from any possible differences in epidermal characters. With the tubers, likewise, our trials show that there is a well-marked difference in fungus resistance resident in the living interior flesh of certain varieties and uniformly distributed through this flesh. This does not prove that there is no difference due to the character of the surface tissues or skin of the potato, as has been advocated by Sorauer (1902). But inasmuch as neither our results nor those of Stuart show any such relation to exist and in view of the evidence previously cited that tuber infection occurs chiefly through breaks in the corky covering, i. e., eyes, wounds, or lenticels, it seems probable that the disease-resistant quality of the tuber is resident entirely within the flesh and quite independent of the character of the skin.

Having decided that the fungus-resistant character is resident within the interior tissues of the leaves and tubers of certain varieties, the attempt was made to learn more as to its nature. Inoculation experiments had already shown the foliage of Irene to be highly resistant, that of Ionia Seedling proved especially susceptible, while Holborn Abundance and Dakota Red were intermediate in resistant qualities. The juice was extracted from these leaves and its degree of acidity determined by titration. That of Irene was found to be +10.6 Fuller's scale; Ionia Seedling, +12.2; Holborn Abundance, +8; and Dakota Red, +14.8. There was no indication, therefore, of any direct relation between the reaction of the juice and the disease-resistant quality of the tissue from which it was extracted. Further evidence on this point was sought by taking the juice from the leaves of Holborn Abundance, normally having the reaction +8 Fuller's scale and dividing it into three parts. One part was made neutral and a second part —8 by the addition of sodium hydroxid. These parts were then sterilized by heating in the steamer for three consecutive days and inoculated with Phytophthora. The growth in all was slow and small in amount. The difference was slight, but was less in the more alkaline (—8) tube than in the others. So far as this result had any significance, therefore, it indicates that the disease-resistant quality was not due to the acidity differences.

The question arose as to whether the resistant quality is still retained in the extracted juice. To determine this a quantity of the juice was expressed from the leaves of each of the three varieties, Irene, Dakota Red, and Ionia Seedling. These were separately passed by suction through Pasteur-Chamberland filters in order to render them sterile and were placed in sterile tubes. These tubes were then inoculated with Phytophthora and held at 18° to 20° C. for some three months. The growth in all the tubes was slow and small in total amount. There was no difference of significance between the amount of the growth in the different juices. Since Irene and Ionia Seedling represent extremes in natural disease resistance the conclusion reached was that the disease-resistant quality is either inseparably associated with the living tissues or else was retained in the mesh of the filter. Experience has shown that enzymes originally in solution may be removed by porcelain filters (Jones, 1909, p. 298). In order further to test this matter the juice was similarly extracted separately from the raw tubers of these same varieties, Irene, Dakota Red, and Ionia Seedling. Part of this juice was simply passed through the Pasteur-Chamberland porcelain filters, part was filtered and in addition heated in the steamer for 15 minutes on each of three successive days, and part of the latter was in turn filtered a second time so as to remove the coagulum resulting from heating. The purpose was to learn if the resistant principle might be destroyed or removed by either the heating or the filtration. Here again the growth was small in all tubes. Since, however, there was no difference of significance as between the different varieties it seems that any disease-resistant property possessed in these original juices was lost in the treatment. Like trials were made with juices expressed from tubers of these varieties which were simply sterilized by heating in the steamer on three consecutive days. These tests also showed no differences of note. Finally tubers of each of the three varieties Irene, Dakota Red, and Ionia Seedling were used in the preparation of potato gelatin, according to the method outlined earlier in this bulletin (p. 47). Here again the growth was essentially alike on the media from all three varieties.

Conclusions.—In view of these results it seems justifiable to conclude that well-marked and fixed differences exist among potato varieties in relative susceptibility to invasion by *Phytophthora infestans;* in other words, in disease resistance. These differences occur in foliage as well as in tuber. While foliage and tuber resistance generally go together, this relation is not invariable. The disease-resistant quality is resident in large measure, and probably wholly, in the interior tissues of both leaf and tuber. In the tuber it is uniformly distributed throughout the flesh. Variations in disease resistance are not correlated with variations in acidity of the tissues. The potato tuber contains but little tannin, and Cook's results indicate that tannin content is not a factor in Phytophthora resistance in the potato. While this resistance may be and indeed probably is due to some chemical product, up to the present time efforts to retain this product, either in the cooked potatoes or in the cooked or filtered juice extracted from the disease-resisting potato varieties, have not succeeded. This product may, therefore, be assumed to be either a compound, modified or destroyed by cooking and weakened or removed by filtration through porcelain, or else it may be so intimately associated with the living protoplasm as to be inseparable from it by the processes employed.

SUMMARY.

1. The potato disease termed the late-blight and rot has been known as the most serious of all potato diseases in Europe and America since about 1845, when its outbreak was the immediate cause of the Irish famine. In the State of New York alone a loss of 20,000,000 bushels in one year was attributed to this disease, and the percentage of loss may be even greater elsewhere.

2. The disease does not attack the leaves, as a rule, until after the blossoming period, i. e., in late summer; if present and weather conditions favor, it quickly causes late-blight, which kills the foliage and thence passes to the tubers, causing the dry-rot.

3. The disease is common in the Northeastern States, being favored by rather cool, moist summers. Farther south and west it is less common, probably only occurring locally when introduced with seed from the North. It does not long persist where the late summers are warm and dry.

4. It is liable to confusion with such leaf diseases as the early-blight (Alternaria) and leaf-blotch (Cercospora) and with various types of tuber rot.

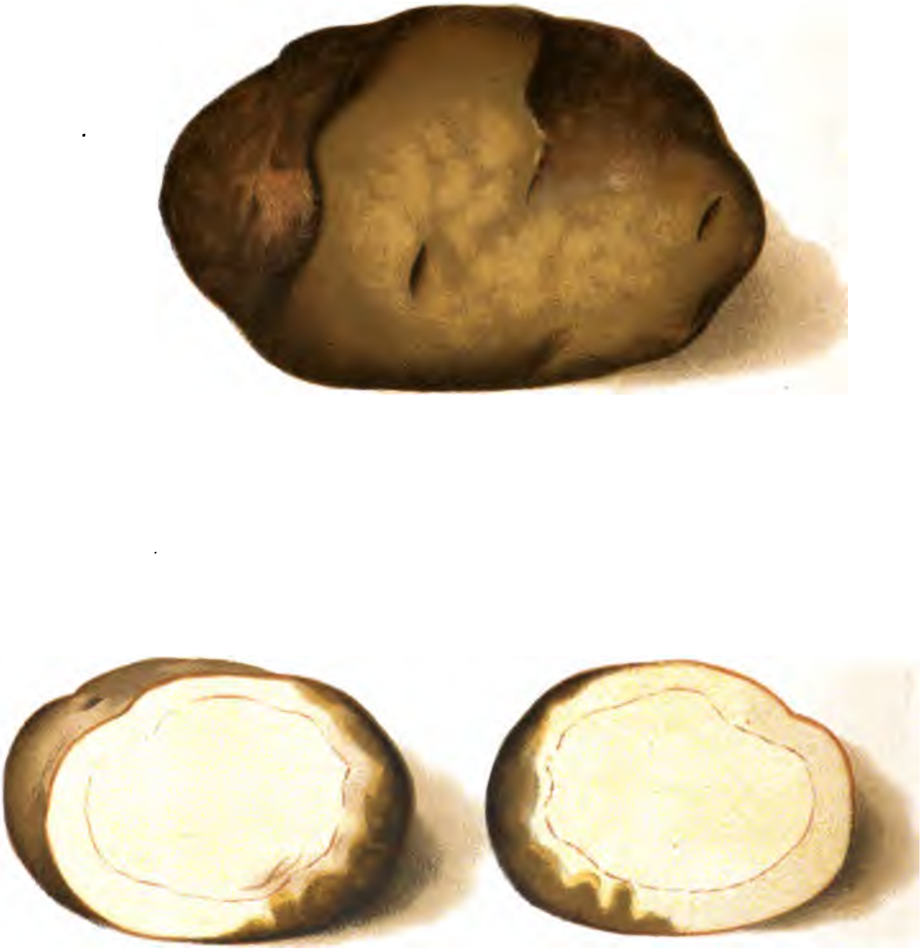
5. It is caused by the fungus *Phytophthora infestans.*

6. The fungus develops first on the foliage, from which it passes by means of spores that are washed into the soil to the tubers, in which it hibernates.

7. Jensen showed the possible efficacy of two remedial measures: (a) Burying the tubers to a sufficient depth (about 4 to 5 inches) with soil to prevent the infection; (b) disinfecting tubers designed for seed purposes by exposure to dry heat, 40° C. (104° F.) for four hours. Neither of these methods has become established in practice.

8. Studies of infection, dissemination, and disease control have shown:

(a) Tuber infection in the field may be prevented by spraying the soil even when the fungus is allowed to develop unchecked on the



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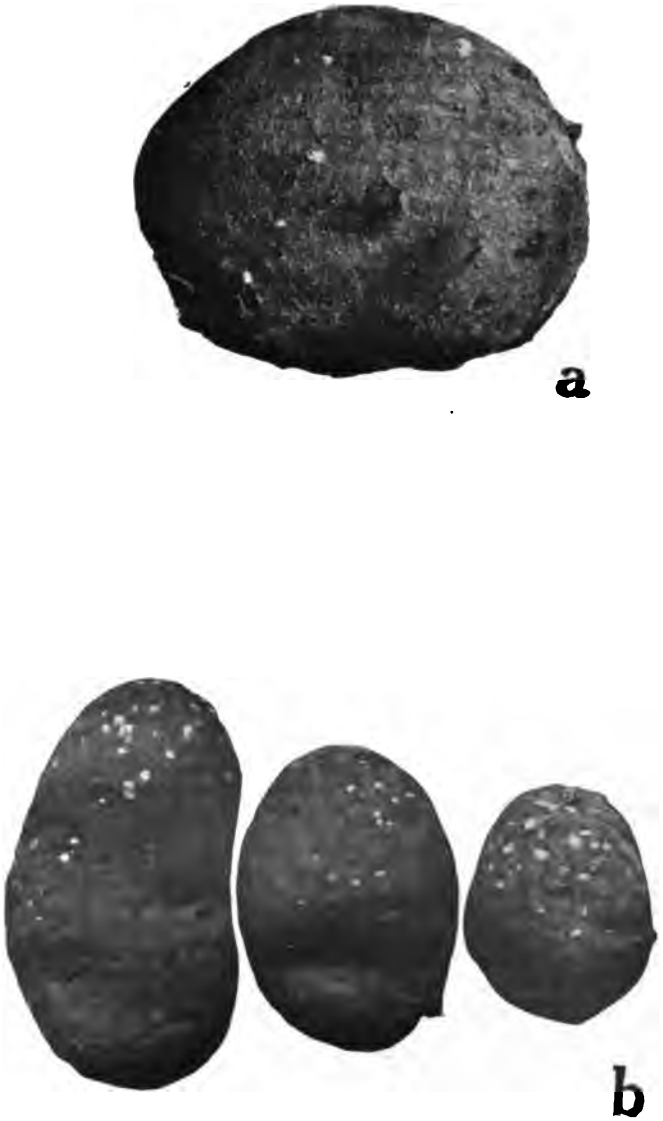
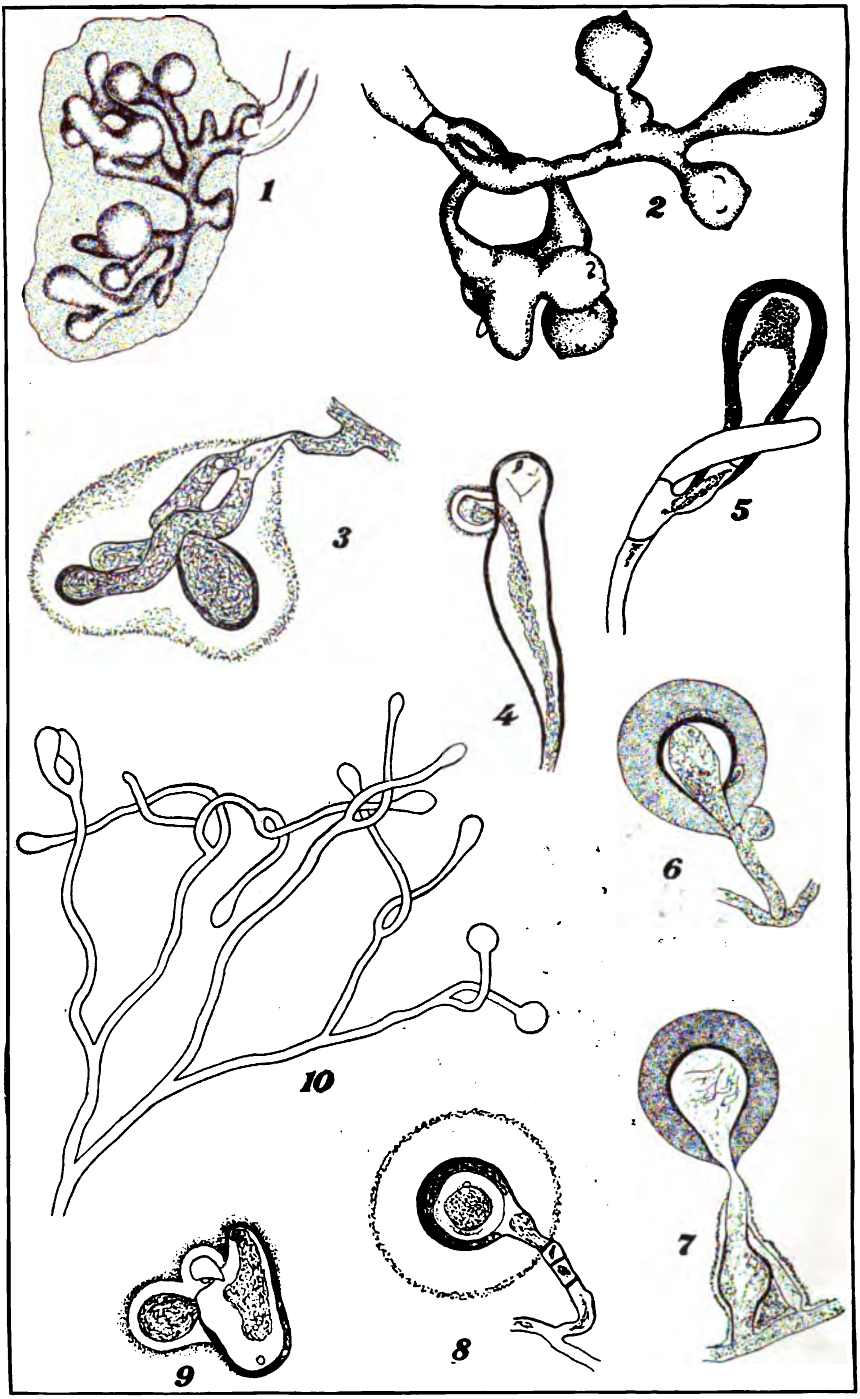
POTATO TUBER SHOWING DRY-ROT CAUSED BY PHYTOPHTHORA.



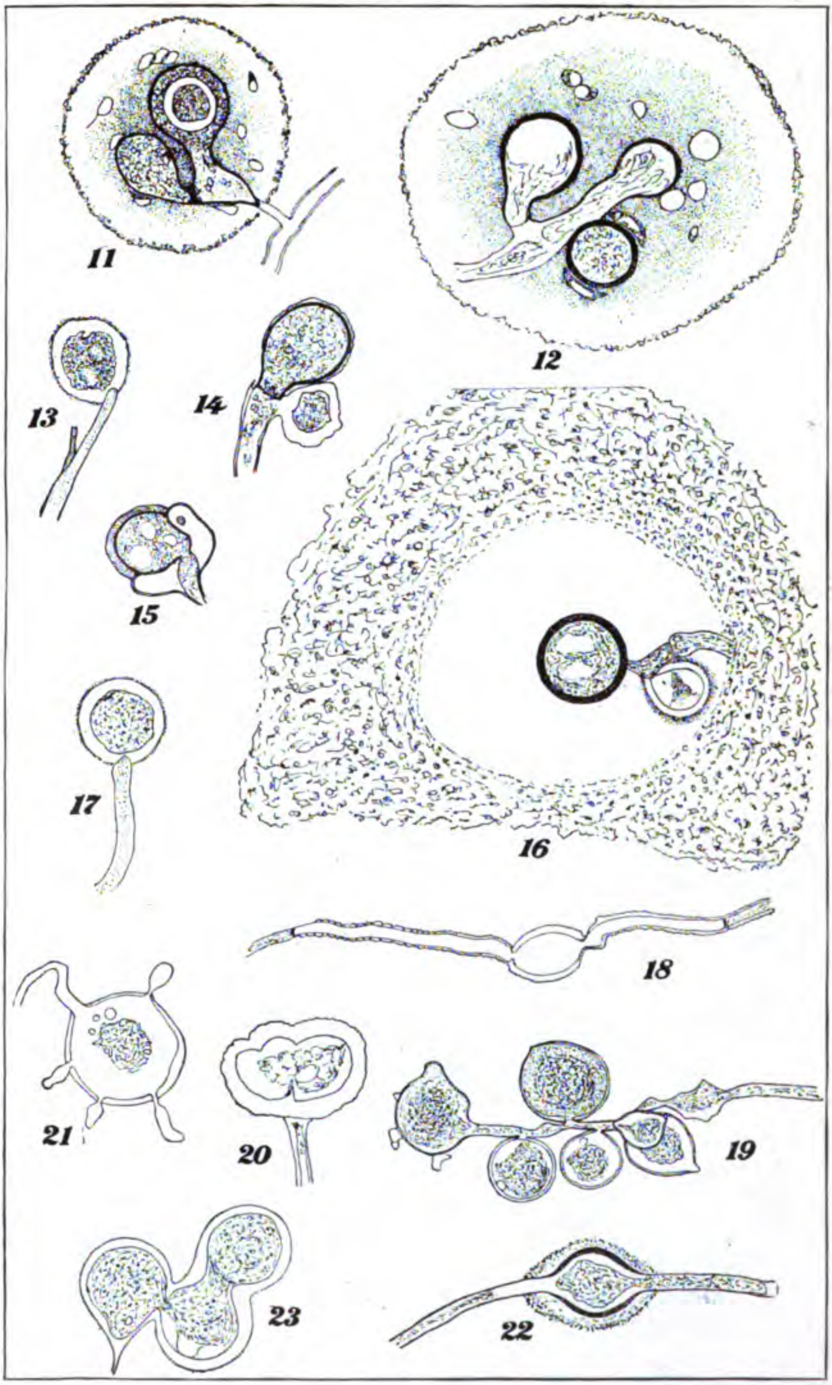
POTATO TUBERS FROM SOIL AND STORAGE, SHOWING WHITE TUFTS OF RICHLY SPORULATING PHYTOPHTHORA INFESTANS DEVELOPING ON THE SURFACE.

[The upper one (*a*) was freshly dug from the field; the lower three (*b*) were from the storage bin in the autumn. About two-thirds natural size.]



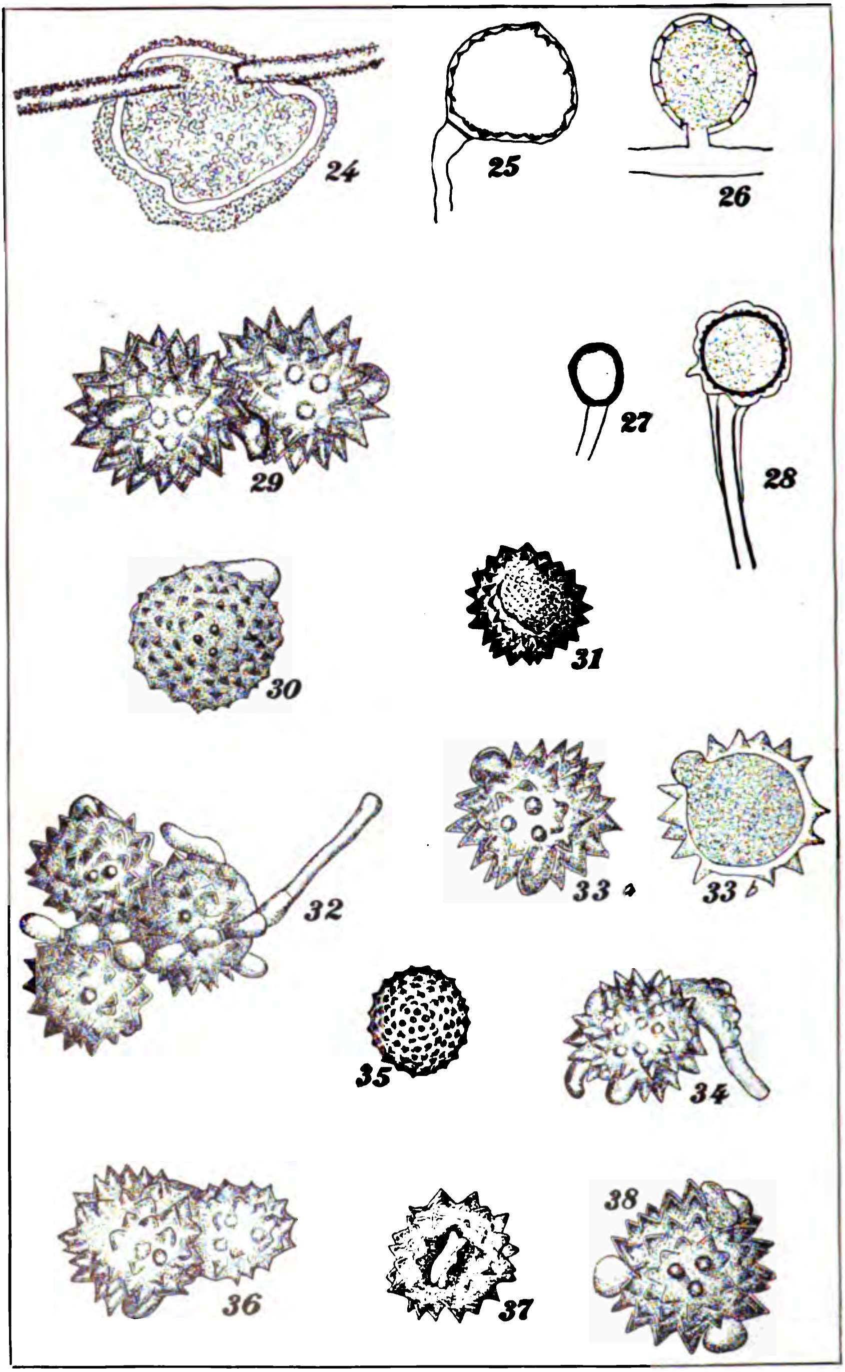
Different Types Shown in the Early Stages of Development of the Resting Bodies as Found in Pure Cultures of Phytophthora Infestans in Potato Gelatin.

[Magnified about 500 diameters, except figure 10, which is magnified about 200 diameters. For details see "Description of plates" and text.]



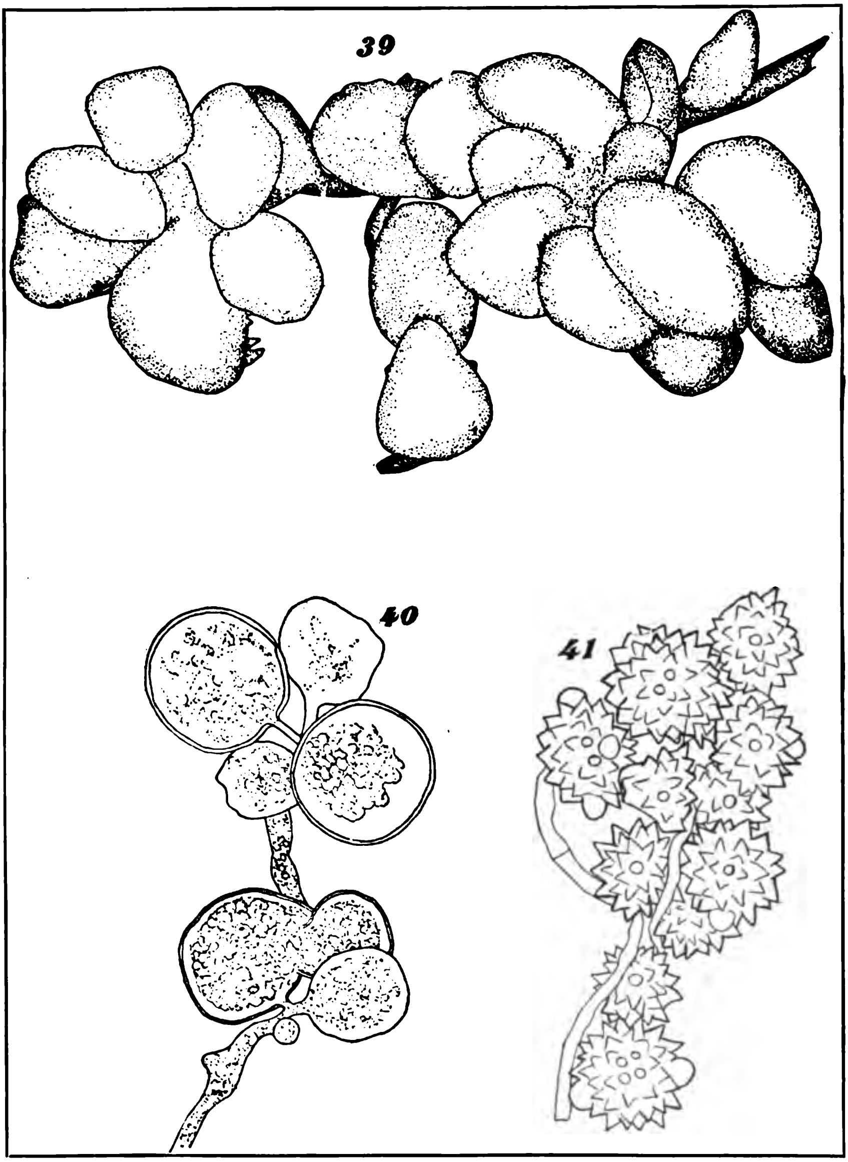
IMMATURE STAGES OF RESTING BODIES FOUND IN POTATO-GELATIN CULTURES OF PHYTOPHTHORA INFESTANS.

[For details see "Description of plates" and text.]



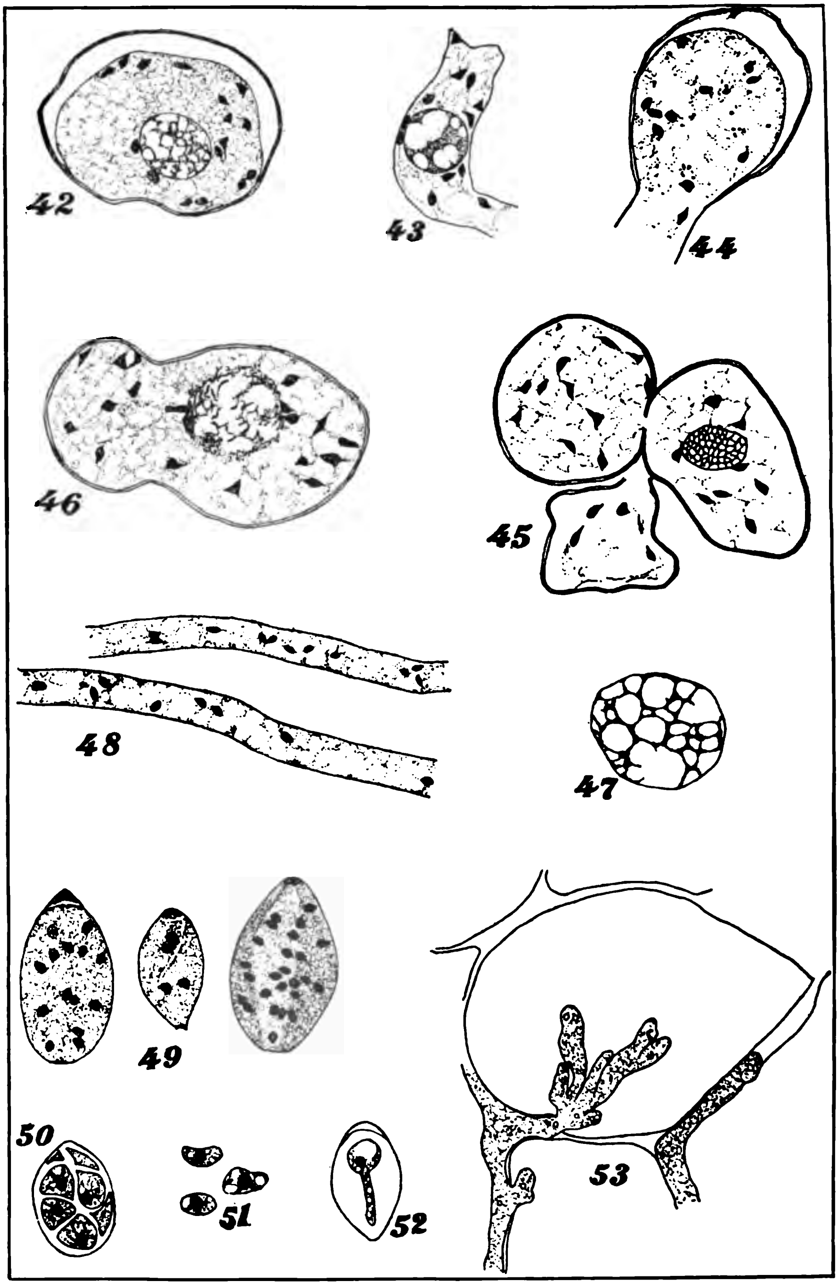
RESTING SPORES FROM POTATO-GELATIN CULTURES OF PHYTOPHTHORA INFESTANS AND SIMILAR BODIES FROM DECAYING POTATO LEAVES.

[Figs. 24–26, immature stages; figs. 29–38, mature stages of resting spores; figs. 27–28, similar bodies found in decaying potato leaves following their invasion by *Phytcphthora infestans*, but considered to be secondary saprophytic organisms.



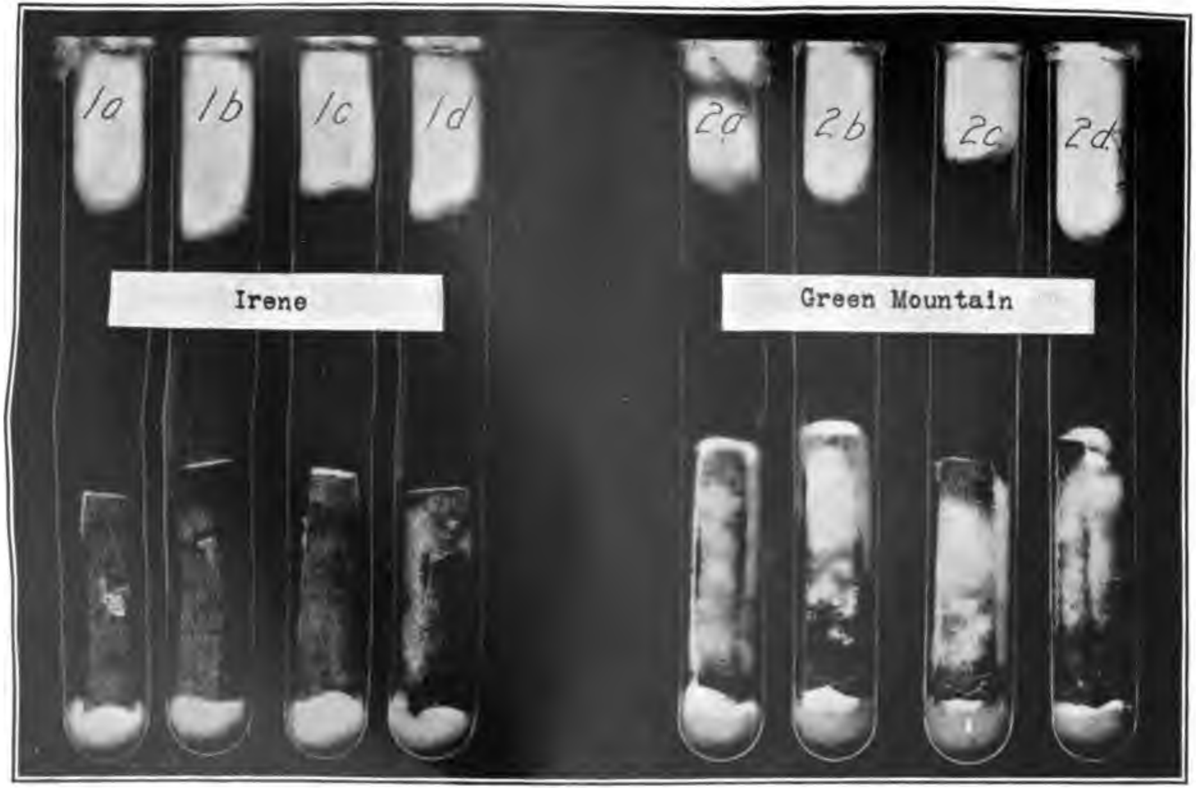
LARGE CLUSTERS OF SPORES FROM POTATO-GELATIN CULTURES OF PHYTOPHTHORA INFESTANS, SHOWING DIFFERENT STAGES OF DEVELOPMENT.

[Figs. 39 and 40, immature; fig. 41, mature; all from the same slide. For details see "Description of plates" and text.]



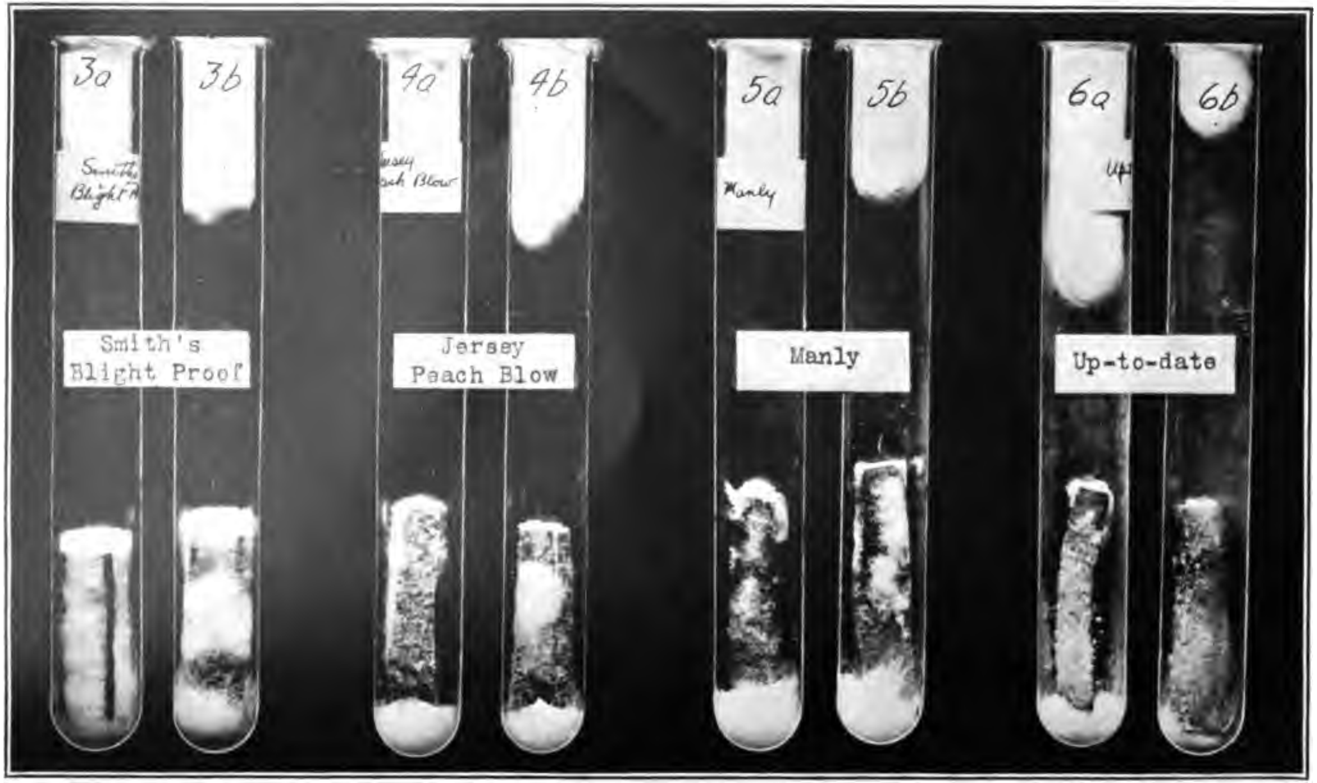
CYTOLOGICAL STUDIES OF PHYTOPHTHORA INFESTANS.

[Figs. 42–47, immature resting-spore structures; fig. 48, mycelium; figs. 49–52, conidia and zoospores (slightly plasmolyzed in fig. 50); fig. 53, haustorium in potato tuber. For further details see "Description of plates" and text.]



PURE CULTURES OF PHYTOPHTHORA INFESTANS, SHOWING 10 DAYS' GROWTH IN TUBES UPON BLOCKS CUT FROM THE INTERIOR OF RAW POTATOES OF VARIETIES WHICH DIFFER IN DISEASE RESISTANCE.

[In the bottom of each tube is a small wad of moist cotton upon which the potato block rests. The German variety Irene (tubes 1*a*–1*d*) shows very little fungous growth—i. e., is highly disease resistant—while the standard American variety Green Mountain (tubes 2*a*–2*d*) shows the vigorous growth characteristic of the highly susceptible varieties. (See also Pl. X.)]



ADDITIONAL PURE CULTURES OF PHYTOPHTHORA INFESTANS, SHOWING 10 DAYS' GROWTH IN TUBES UPON BLOCKS CUT FROM THE INTERIOR OF RAW POTATOES OF VARIETIES WHICH DIFFER IN DISEASE RESISTANCE.

[These cultures show a gradation from the American variety Smith's Blightproof (tubes 3*a*, 3*b*), highly susceptible, through Jersey Peachblow (4*a*, 4*b*) and Manly (5*a*, 5*b*) to the highly disease-resistant English variety Up-to-Date (6*a*, 6*b*). This laboratory method of determining disease resistance promises to be both more reliable and more expeditious than field trials. (For details see "Description of plates" and text, especially Table XI.)]

foliage. This is explainable only on the assumption that the primary tuber infection comes from spores washed through the soil.

(b) Tubers may also be infected from contact with blighting foliage at digging time.

(c) Secondary infection of tubers may occur either in the soil before digging or in the storage bin from spores developed on the surface of earlier infected tubers.

(d) When the tops are attacked by late-blight the harvesting of the tubers should be delayed until a week or more after the death of the tops. Longer delay does no harm unless the season be wet and the soil exceptionally heavy.

(e) Dry, cool storage is of primary importance, the use of lime or formalin disinfection for the tubers being valueless.

(f) Wind and water are probably the important agencies in local spore distribution, but leaf-eating insects also function and may carry the spores longer distances.

(g) Spraying the foliage with Bordeaux mixture has proved an almost complete remedy against both the Phytophthora blight and the rot, and also operates beneficially to the potato plant in other ways. Spraying experiments with this mixture have been made annually at the Vermont experiment station for 20 years, 1891 to 1910, on late or main-crop potatoes, three applications generally being made. The results were an increased yield in every case, ranging from 18 to 215 per cent. The average of the yields of the 20 years on the sprayed areas was 268 bushels per acre as compared with 163 bushels on the unsprayed, a gain of 105 bushels per acre, or 64 per cent.

9. *Phytophthora infestans* has been carried in pure culture since 1904, and some strains have been thus grown continuously for over five years without evidence of change in pathogenicity or other characters. It grows best on blocks cut from the interior of raw potato, very well on Lima-bean agar and potato gelatin, and also, as recently shown by Clinton, on oat agar. It has been grown, but with less vigor, on various other vegetables and synthetic media.

10. The fungus in culture will survive a fairly wide range in the reaction of the medium. Fructification was checked by an alkalinity of −3 Fuller's scale and by an acidity of +15. Vegetative growth occurred between −8 and +25. These facts are of possible interest in connection with the relation of the fungus both to the host tissues and to fungicides.

11. Exposing test-tube cultures for 10 minutes at temperatures up to 40° C. did not prevent the later development of the fungus; beyond this temperature inhibition resulted. Where cultures were held at constant temperatures the best growths resulted between 16° and 19° C. Below 16° C. the growth was slower, and below 5° C. it was

wholly inhibited. At and above 23° C. the growth was inhibited, with no sporulation above 25° and no vegetative growth at or above 30°.

12. Bodies having the characters of thick-walled spiny resting spores were produced in pure cultures in potato gelatin and in Lima-bean agar. In the early stages of their development these bodies had the general appearance and the cytological characters of oogonia, but no antheridia were found, and they apparently developed asexually. Nine strains of the fungus from widely different sources in America and Europe have been studied with reference to the production of these bodies. They were found in all. Growth in mixed culture did not increase or modify them. Persistent search failed to reveal the mature stages of these bodies in cultures upon blocks cut from potato tubers, although what were considered to be immature stages of the same bodies were found sparingly. No such bodies have been found in decaying potato tubers following Phytophthora attacks. Examination of potato leaves killed by Phytophthora showed that somewhat similar bodies occur. Some of them clearly originated from secondary saprophytes and probably all so originated. No opinion is therefore justified as to the occurrence of such resting spores in nature, although their appearance in the culture tubes proves that Phytophthora is capable of developing such bodies. In no case have these spores been seen to germinate.

13. Inoculations of potato leaves of different varieties with Phytophthora cultures showed that certain varieties are much more susceptible than others. This difference was shown in the rate of progress through the leaves following infection as well as in the number of leaves infected. This fact indicates that the disease-resistant quality is largely, if not wholly, resident within the mesophyll and that it is independent of epidermal characters.

14. Inoculations of sterile blocks cut from the flesh of potato tubers with Phytophthora cultures showed a wide range in vigor of growth, i. e., in Phytophthora-resisting properties. Blocks cut from different parts of the same tuber, and also from different tubers of the same variety, gave essentially like results. There was much difference, however, as between varieties. This difference was sufficiently marked to permit of their being graded on a percentage basis with a fair degree of assurance and to enable one to distinguish with full confidence between the especially disease-resistant varieties and those that were more susceptible.

15. A comparison of the conclusions reached by this laboratory method, using pure cultures for determining the relative disease-resistant quality of potato tubers, with the amount of tuber rot recorded by Stuart from field trials of the same varieties gives ground for confidence in its reliability as a method of judging of the rot-

resistant qualities of the variety under trial. It is a method having at least much value as supplementing field trials for the determination of disease resistance, if not of replacing them entirely.

16. These studies confirmed the conclusions reached by Stuart from his field trials that certain standard European varieties are much more highly resistant to Phytophthora attacks than are the standard American varieties.

17. Efforts to determine more definitely the location or nature of the disease-resisting property gave little that was definite beyond the fact that it was resident within the flesh of the living potato tuber and uniformly distributed through it. The difference was not correlated with differences in the relative acidity of the sap or in any other chemical factor determined and it apparently was lost with the extraction of the juice and with cooking.

INDEX TO LITERATURE.

A list of the literature of the potato fungus *Phytophthora infestans* and related matters referred to in this bulletin follows:

Appel, Otto, and Kreitz, Wilhelm. Der derzeitige Stand unserer Kenntnisse von den Kartoffelkrankheiten und ihrer Bekämpfung. Mitteilungen, Kaiserliche Biologische Anstalt für Land- und Forstwirtschaft, no. 5, August, 1907.

Bary, Anton de. Sur la formation de zoospores chez quelques champignons. Annales des Sciences Naturelles, Botanique, ser. 4, vol. 13, 1860, pp. 236–250, pl. 13.

——— Die gegenwärtig herrschende Kartoffelkrankheit, ihre Ursache und ihre Verhütung, Leipzig, 1861, 1 pl.

——— Recherches sur le développement de quelques champignons parasites. Annales des Sciences Naturelles, Botanique, ser. 4, vol. 20, 1863, pp. 5–148.

——— Researches into the nature of the potato-fungus, Phytophthora infestans. Journal of Botany, vol. 14, 1876, pp. 105–126, 149–154, 8 figs.

——— Researches into the nature of the potato-fungus, Phytophthora infestans. Journal of the Royal Agricultural Society of England, ser. 2, vol. 12, 1876, pp. 239–269.

——— Zur Kenntniss der Peronosporeen. Botanische Zeitung, vol. 39, 1881, no. 33, pp. 521–530; no. 34, pp. 537–544; no. 35, pp. 553–563; no. 36, pp. 569–578; no. 37, pp. 585–595; no. 38, pp. 601–609; no. 39, pp. 617–625, pl. 5.

——— and Woronin, M. Beiträge zur Morphologie und Physiologie der Pilze. Ser. 4. Untersuchungen über die Peronosporeen und Saprolegnieen und die Grundlagen eines natürlichen Systems der Pilze. 6 pls. Frankfort on the Main, 1881.

Brefeld, O. Mucor racemosus und Hefe. Flora, vol. 56, 1873, pp. 385, 391.

Bush, Andrew. Rot in potatoes. Transactions of the New York State Agricultural Society, vol. 5, 1845, pp. 342–348. 1846.

Clinton, G. P. Downy mildew, or blight, Phytophthora infestans (Mont.) De By., of potatoes.—II. Twenty-Ninth Annual Report of the Connecticut Agricultural Experiment Station, 1905, pp. 304–329, pls. 23–25. 1906.

——— Artificial cultures of Phytophthora, with special reference to oospores. Thirty-First and Thirty-Second Annual Reports of the Connecticut Agricultural Experiment Station, 1908, pp. 891–907, pls. 70–71.

——— Oospores of potato blight, Phytophthora infestans. Thirty-Third and Thirty-Fourth Annual Reports of the Connecticut Agricultural Experiment Station, 1909–10, pp. 753–774. 1910.

Coleman, L. C. Diseases of the areca palm (*Areca catechu* L.). Annales Mycologici, vol. 8, 1910, no. 6, pp. 591–626, 4 figs., pls. 7–9.

Cook, M. T. The toxic properties of tannin. Science, n. s., vol. 31, 1910, no. 802, pp. 751–752.

Cooke, M. C. Rust, smut, mildew & mould, 2d ed., London, 1870, p. 145.

——— Plant diseases and fungi. Essex Naturalist, vol. 6, 1892, no. 1/3, pp. 18–31.

Cornu, Maxime. Note sur le Phytophthora infestans de Bary et les spores dormantes qui l'accompagnent (*Pythium vexans* de Bary et *Artotrogus hydnosporus* Mont.). Bulletin, Société Botanique de France, vol. 28 (ser. 2, vol. 3), 1881, pp. 102–109.

Davis, B. M. The fertilization of Albugo candida. Botanical Gazette, vol. 29, 1900, no. 5, pp. 297–311, pl. 22. Reprinted as No. 19 of Contributions from the Hull Botanical Laboratory.

Delacroix, Georges. Sur la pourriture des pommes de terre. Bulletin de la Société Mycologique de France, vol. 19, 1903, no. 4, pp. 356–376.

——— Sur une altération des tubercules de pomme de terre dans la région avoisinant Paris pendant le mois de septembre 1903. Annales de l'Institut National Agronomique, ser. 2, vol. 3, 1904, pt. 1, pp. 37–74, 2 figs.

Farlow, W. G. The potato rot. Bulletin, Bussey Institution, vol. 1, 1875, pp. 319–338.

Fjeldstrup, M. [Potato disease in Denmark.] Tidsskrift for Landøkonomi, 1844, p. 491.

Güssow, H. T. A serious potato disease occurring in Newfoundland. Bulletin 63, Division of Botany, Canada Central Experimental Farm, 1909.

Hallier Ernst. Phytopathologie, Leipzig, 1868.

Harrison, F. C. A bacterial rot of the potato, caused by Bacillus solanisaprus. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, pt. 2, vol. 17, 1906, no. 1/2, pp. 34–39; no. 3/4, pp. 120–128; no. 5/7, pp. 166–174; no. 11/13, pp. 384–394, pls. 1–8.

Hecke, Ludwig. Untersuchungen über Phytophthora infestans De By., als Ursache der Kartoffelkrankheit. Journal für Landwirtschaft, vol. 46, 1898, no. 1, pp. 71–74; no. 2, pp. 97–142. 4 pls.

Heinemann, P. G. A substitute for potato as a culture medium. Journal of Infectious Diseases, vol. 4, 1907, no. 2, pp. 282–284.

Holle, Gustav von. Ueber den Kartoffelpilz. 5.—Ueber die Ursachen der Kartoffelkrankheit. Botanische Zeitung, vol. 16, 1858, no. 6, pp. 45–53.

Jensen, J. L. Moyens de combattre et de détruire le Peronospora de la pomme de terre. Mémoires, Société Nationale d'Agriculture de France, vol. 131, 1887, pp. 31–156.

Jones, L. R. Potato blight and rot. Bulletin 24, Vermont Agricultural Experiment Station, 1891.

——— Potato blight and rot. Fourth Annual Report of the Vermont Agricultural Experiment Station, 1890, pp. 131–135. 1891.

——— Spraying potatoes. Bulletin 40, Vermont Agricultural Experiment Station, 1893.

——— Potato blights. I.—Relation of the late-blight to the weather. Ninth Annual Report of the Vermont Agricultural Experiment Station, 1895, pp. 66–71. 1896.

JONES, L. R. Certain potato diseases and their remedies. Bulletin 72, Vermont Agricultural Experiment Station, September, 1899.

——— The diseases of the potato in relation to its development. Transactions of the Massachusetts Horticultural Society, 1903, pt. 1, pp. 144–156.

——— Disease resistance of potatoes. Bulletin 87, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1905. Abridged in Eighteenth Annual Report of the Vermont Agricultural Experiment Station, 1904–5, pp. 264–267. 1905.

——— Pectinase, the cytolytic enzym produced by Bacillus carotovorus and certain other soft-rot organisms. Technical Bulletin 11, pt. 2, New York Agricultural Experiment Station, 1909; also Bulletin 147, pt. 2, Vermont Agricultural Experiment Station, 1909.

——— Resting spores of the potato fungus (Phytophthora infestans). Science, n. s., vol. 30, 1909, pp. 813–814.

——— and GIDDINGS, N. J. Studies of the potato fungus, Phytophthora infestans. Science, n. s., vol. 29, 1909, no. 737, p. 271.

——— and LUTMAN, B. F. Further studies of Phytophthora infestans. Science, n. s., vol. 31, 1910, no. 802, pp. 752–753.

——— and MORSE, W. J. Potato diseases and their remedies. III.—Relation of date of digging to development of rot. Fifteenth Annual Report of the Vermont Agricultural Experiment Station, 1901–2, pp. 219–223. 1902.

——— ——— Potato diseases and their remedies. II.—Relations of date of digging to development of rot. Sixteenth Annual Report of the Vermont Agricultural Experiment Station, 1902–3, pp. 161–162. 1903.

——— ——— Potato diseases and their remedies. II.—Relation of date of digging to development of rot. Seventeenth Annual Report of the Vermont Agricultural Experiment Station, 1903–4, pp. 391–395. 1905.

——— ——— Potato diseases and their remedies. Eighteenth Annual Report of the Vermont Agricultural Experiment Station, 1904–5, pp. 272–291. 1905.

——— and POMEROY, C. S. The leaf blotch disease of the potato caused by Cercospora concors. Ninteenth Annual Report of the Vermont Agricultural Experiment Station, 1905–6, pp. 236–256, figs. 3–5. 1907.

KAUFFMAN, C. H. A contribution of the physiology of the Saprolegniaceæ. Annals of Botany, vol. 22, 1908, pp. 361–387.

KLEBAHN, HEINRICH. Krankheiten des Flieders, Berlin, 1909, 45 pls.

KLEBS, G. Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen, Jena, 1896, p. 517.

——— Zur Physiologie der Fortpflanzung einiger Pilze. Jahrbücher für Wissenschaftliche Botanik, vol. 33, 1899, p. 513, and vol. 35, 1900, p. 80.

LUTMAN, B. F. Plant diseases; potato spraying. Bulletin 153, Vermont Agricultural Experiment Station, 1910.

——— Plant diseases. Twenty years' spraying for potato diseases. Potato diseases and the weather. Bulletin 159, Vermont Agricultural Experiment Station, 1911.

MANGIN, LOUIS. Recherches sur les Péronosporées. Bulletin 8, Société d'Histoire Naturelle d'Autun, 1895, pp. 55–108.

MARTIUS, C. F. P. VON. Die Kartoffel-Epidemie der letzten Jahre oder die Stockfäule und Räude der Kartoffeln, Munich, 1842, 3 pls.

Matruchot, L., and Molliard, M. Sur le Phytophthora infestans. Annales Mycologici, vol. 1, 1903, no. 6, pp. 540–543.

Minott, C. W. Experiment with a fungicide. Third Annual Report of the Vermont Agricultural Experiment Station, 1889, pp. 117–118. 1890.

Montagne, J. F. C., [Note sur la maladie qui ravage les pommes de terre et caractères du Botrytis infestans.] Société philomatique de Paris. Extraits des procès-verbaux des séances pendant l'année 1845, pp. 98–101.

Morren, C. F. A. Nouvelles instructions populaires sur les moyens de combattre et de détruire la maladie actuelle (Gangrene humide) des pommes de terre, Paris, 1845, 48 pp.

Morse, W. J. Two recent epidemics of late-blight and rot of potatoes in Aroostook County. Bulletin 169, Maine Agricultural Experiment Station, 1909.

——— Blackleg. A bacterial disease of the stem and tuber of the Irish potato. Bulletin 174, Maine Agricultural Experiment Station, 1909.

Norton, J. P. The potato disease in Scotland. Transactions of the New York State Agricultural Society, vol. 5, 1845, pp. 349–379. 1846.

Orton, W. A. Plant diseases in the United States. Yearbook, U. S. Dept. of Agriculture, for 1901, pp. 668–672; for 1902, pp. 714–719; for 1903, pp. 550–555; for 1904, pp. 581–586; for 1905, pp. 602–611; for 1906, pp. 499–508.

——— Decay of potatoes due to Rhizopus nigricans. Science, n. s., vol. 29, 1909, no. 753, p. 916.

——— and Ames, Adeline. Plant diseases in the United States. Yearbook, U. S. Dept. of Agriculture, for 1907, pp. 577–589; for 1908, pp. 533–538.

——— and Field, Ethel C. Wart disease of the potato; a dangerous European disease liable to be introduced into the United States. Circular 52, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1910.

Pfeffer, W. F. P. The physiology of plants, 2d ed., vol. 1, 1900, p. 275.

Phillips, Henry. History of cultivated vegetables, 2 vols., London, 1822.

Plowright, C. B. Jensen on the potato disease. Gardeners' Chronicle, n. s., vol. 21, 1884, pp. 208, 239–240, 273–274.

Prillieux, E. E. Rapport sur l'emploi de la chaux et du sulfate de cuivre contre le mildew. Bulletin, Ministère de l'Agriculture, France, vol. 5, 1886, no. 1, pp. 24–29.

——— Expérience sur le traitement de la maladie de la pomme de terre. Comptes Rendus, Académie des Sciences, Paris, vol. 107, 1888, no. 8, pp. 447–448.

Prunet, Adolphe. Le mildiou de la pomme de terre. Revue de Viticulture, vol. 17, 1902, no. 443, pp. 663–666; vol. 18, 1902, no. 449, pp. 97–104; no. 451, pp. 156–162; no. 455, pp. 267–269; no. 458, pp. 354–359.

Rolfs, F. M. Potato failures. A Preliminary Report. Bulletin 70, Colorado Agricultural Experiment Station, 1902.

——— Potato failures. A second report. Bulletin 91, Colorado Agricultural Experiment Station, 1904.

Roze, Ernest. Histoire de la pomme de terre, Paris, 1898, 464 pp., illustrated.

——— Du Phytophtora infestans de Bary et de la pourriture des pommes de terre. Bulletin de la Société Mycologique de France, vol. 14, 1898, no. 2, pp. 58–69.

Selby, A. D. A rosette disease of potatoes, attributed to the sterile fungus Rhizoctonia. Bulletin 139, Ohio Agricultural Experiment Station, 1903.

——— Studies in potato rosette.—II. Bulletin 145, Ohio Agricultural Experiment Station, 1903.

Smith, E. F. A bacterial disease of the tomato, eggplant, and Irish potato. (*Bacillus solanacearum* n. sp.) Bulletin 12, Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture, 1896.

——— Bacillus phytophthorus Appel. Science, n. s., vol. 31, 1910, no. 802, pp. 748–749.

——— and Swingle, D. B. The dry rot of potatoes due to Fusarium oxysporum. Bulletin 55, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1904.

Smith, W. G. The resting-spores of the potato disease. Gardeners' Chronicle, n. s., vol. 4, 1875, no. 80, pp. 35–36; no. 81, pp. 68–70; no. 82, p. 101; no. 83, p. 130; no. 92, p. 433, figs. 9–13, 19; see also editorial note, p. 44; report of the Royal Horticultural Society, p. 179; correspondence of Alexander Bean, p. 496; correspondence of William Tillery, p. 530.

——— The resting spores of the potato fungus. Monthly Microscopical Journal, vol. 14, 1875, pp. 110–129, pls. 114–116.

——— The potato fungus. Germination of the resting-spores. Grevillea, vol. 5, 1876, no. 33, pp. 18–24, pls. 70–73.

——— The potato fungus. Germination of the resting-spores. Gardeners' Chronicle, n. s., vol. 6, 1876, no. 132, pp. 39–43, figs. 12–13; also in Monthly Microscopical Journal, vol. 16, 1876, pp. 120–135, pls. 151–154.

Smorawsky, Josef. Zur Entwickelungsgeschichte der Phytophthora infestans (Montagne) De By. Inaugural dissertation, Erlangen. Landwirtschaftliche Jahrbücher, vol. 19, 1890, pp. 1–12, pl. 1.

Snyder, Harry. The composition, digestibility, and food value of potatoes. Bulletin 42, Minnesota Agricultural Experiment Station, 1896.

Sorauer, Paul. Einige Beobachtungen bei der Anwendung von Kupfermitteln gegen die Kartogelkrankheit. Zeitschrift für Pflanzenkrankheiten, vol. 3, 1893, pp. 32–36.

——— Ueber die Prädisposition der Pflanzen für Parasitäre Krankheiten. Jahresbericht der Sonderausschusses für Pflanzenschutz, no. 12, 1902, pp. 193–210. (Arbeiten der Deutschen Landwirtschafts-Gesellschaft, no. 82, 1902.)

Speerschneider, J. Dass das Faulen der Kartoffelknollen bei der sogenannten Kartoffelkrankheit durch die ausgestreuten und keimenden Sporen des Blattpilzes (*Peronospora devastatrix*) verursacht wird, durch Experimente bewiesen. Flora, vol. 40 (n. s., vol. 15), 1857, no. 6, pp. 81–87.

——— Die Ursache der Erkrankung der Kartoffelknolle durch eine reihe Experimente bewiesen. Botanische Zeitung, vol. 15, 1857, no. 8, pp. 121–125.

Stevens, F. L. The compound oosphere of Albugo bliti. Botanical Gazette, vol. 28, 1899, no. 3, pp. 149–176; no. 4, pp. 225–245, pls. 11–15. Reprinted as No. 16 of Contributions from the Hull Botanical Laboratory.

——— Gametogenesis and fertilization in Albugo. Botanical Gazette, vol. 32, 1901, no. 2, pp. 77–98; no. 3, pp. 157–169; no. 4, pp. 238–261, pls. 1–4. Reprinted as No. 29 of Contributions from the Hull Botanical Laboratory.

Stewart, F. C., Eustace, H. J., and Sirrine, F. A. Potato spraying experiments in 1902. Bulletin 221, New York Agricultural Experiment Station, 1902.

——— ——— ——— Potato spraying experiments in 1903. Bulletin 241, New York Agricultural Experiment Station, 1903.

——— French, G. T., McMurran, S. M., and Sirrine, F. A. Potato spraying experiments in 1909. Bulletin 323, New York Agricultural Experiment Station, 1910.

Stuart, William. Disease-resistant potatoes. Bulletin 115, Vermont Agricultural Experiment Station, 1905.

——— Disease Resistance of Potatoes. Bulletin 122, Vermont Agricultural Experiment Station, 1906.

Sturgis, W. C. Notes on the "early blight" of potatoes. Eighteenth Annual Report of the Connecticut Agricultural Experiment Station 1894, pp. 127–133. 1895.

Sutton, A. W. Potatoes. Reprinted from Journal of the Royal Horticultural Society, vol. 19, 1895, pt. 3.

Unger, Franz. Beitrag zur Kenntniss der in der Kartoffelkrankheit vorkommenden Pilze und der Ursache ihres Entstehens. Botanische Zeitung, vol. 5, p. 314. 1847.

Wager, Harold. On the structure and reproduction of Cystopus candidus, Lév. Annals of Botany, vol. 10, 1896, no. 39, pp. 295–342, pls. 15–16.

Ward, H. M. Illustrations of the structure and life-history of Phytophthora infestans, the fungus causing the potato disease. Quarterly Journal of Microscopical Science, n. s., vol. 27, 1887, no. 107, pp. 413–425, pls. 31–32.

Watson, T. L. A chemical study of the Irish potato. Pt. I.—Analysis of the tubers. Pt. II.—Comparison of tubers grown in different States, Bulletins 55 and 56, Virginia Agricultural Experiment Station, 1895.

Westrem, M. [Potato disease in Norway.] Tidsskrift for Landøkonomi, 1851, p. 412.

Wilson, G. W. Studies in North American Peronosporales.—II. Phytophthoreæ and Rhysotheceæ. Bulletin of the Torrey Botanical Club, vol. 34, 1907, no. 8, pp. 387–416.

DESCRIPTION OF PLATES.

PLATE I. Potato leaf badly attacked by the late-blight fungus *Phytophthora infestans*. (From a painting by Mrs. W. J. Morse.)

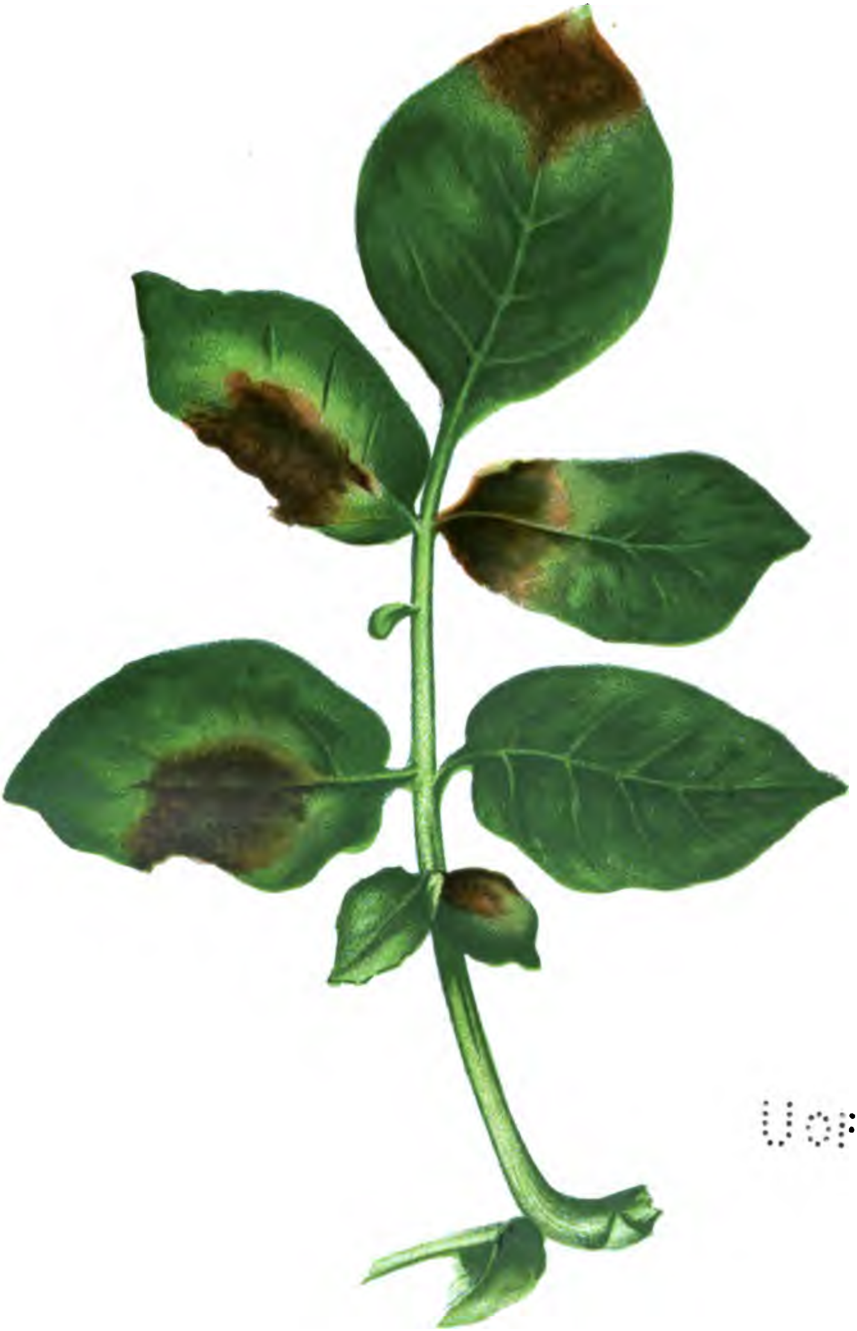
PLATE II. Potato tuber with the sunken dark areas characteristic of Phytophthora infection, the condition commonly known as dry-rot. (From a painting by Mrs. W. J. Morse.)

PLATE III. Phytophthora-infected tubers with the fungus fruiting on their surfaces. Microscopic examination showed the white spots to consist of *Phytophthora infestans*, richly sporulating. (*a*) Tuber just as dug from the soil with several such fungous tufts. (*b*) Tubers from storage cellar still more abundantly studded with Phytophthora outgrowths.

PLATES IV–VIII. Drawings of *Phytophthora infestans*. All figures in these plates, unless otherwise specified, were drawn by the aid of a camera lucida from material grown in pure culture. Figs. 1–33*b* are magnified about 500 times. Figs. 29–53 are magnified 1,000 times, except No. 48, which is 2,000 times. Figs. 1–16.—These 16 illustrations represent different types and stages in the development of the resting bodies found in our earlier potato-gelatin cultures. Some of these bodies are brown walled, while others, such as Nos. 8, 11, and 12, have a gelatinous and practically transparent outer covering, usually very much swollen, inclosing a dark-brown inner wall (figs. 5, 6, and 7). Fig. 16 shows the condition and also the granular halo in the gelatin which enveloped the outer coating. Some of the others, such as Nos. 3, 8, 10, 11, 12, and 13, show this granular layer more diffused or developed in a less marked degree. Figs. 17–23.—Clear-walled, apparently immature resting spores such as were abundant in our later culture. It will be noticed that these bodies are usually formed apically, or as side branches, but may be formed intercalary in the hyphæ. Fig. 19 shows the general resemblance of at least some of these bodies to the conidia. Figs. 25 and 26.—Clear-walled spores, but with inner portion of wall tinged with brown. Spines are apparently beginning to form in the interior. Figs. 27 and 28.—Brown-walled spores obtained from teasing Phytophthora-infected potato leaves, probably saprophytic intruders. Figs. 29–38.—Thick, brown-walled, spiny resting spores, such as have been found in our later old potato-gelatin cultures. Fig. 33*a* is a surface view of such a spore, while fig. 33*b* is a median optical section of same. Figs. 39, 40, and 41.—Clusters from potato-gelatin culture. No. 40 is clear walled; No. 39 has dark-brown, almost smooth walls; No. 41, spiny dark-brown walls. These three clusters were obtained from one slide and evidently represent different stages or types of development. Figs. 42–46.—Stained sections of immature resting spores, showing the nuclei and the peculiar structures suggestive of aborted oospheres. Fig. 47.—Details of section of one of these interior bodies. Fig. 48.—Some of the mycelium from the pure cultures showing the nuclei. Fig. 49.—Conidia stained to show nuclei. Fig. 50.—Conidium cut up into zoospores; stained to show nuclei. Fig. 51.—Zoospores stained on slide to show nucleus in each. The cilia are not stained. Fig. 52.—Zoospore which has not escaped from conidium, putting out a germ tube; nucleus stained. Fig. 53.—Haustorium from mycelium in potato tuber penetrating host cell. Drawing from a preparation courteously furnished by Dr. Delacroix.

PLATE IX.—Tube cultures, 10 days old, of *Phytophthora infestans* on raw-potato blocks, showing different degrees of susceptibility or disease resistance. Tubes 1*a* to 1*d*, Irene; tubes 2*a* to 2*d*, Green Mountain. By comparison with Table XI (p. 77) it will be seen that the Irene represents the highly disease-resistant varieties (group 1, p. 77). It is not, however, the most highly resistant of these, its average growth being rated at 11 per cent (p. 77). Green Mountain is representative of the highly susceptible varieties (group 5, p. 78), showing an average growth rated at 95 per cent. Hundreds of such cultures have been made of these two varieties, using scores of tubers and from the crops of two seasons, with similar results.

PLATE X.—Cultures similar to those of Plate IX, showing four varieties: Tubes 3*a* and 3*b*, Smith's Blightproof, a highly susceptible American variety representing group 5. The next two varieties—Jersey Peachblow and Manly—also American, represent the moderately resistant varieties (group 2). Up-to-Date is a highly resistant English variety representing group 1. (For further details see text under "Disease resistance of potatoes," p. 69.)



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POTATO LEAVES SHOWING LATE-BLIGHT CAUSED BY PHYTOPHTHORA.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 246.

B. T. GALLOWAY, *Chief of Bureau.*

THE RELATION OF BARIUM TO THE LOCO-WEED DISEASE.

I.—A FIELD STUDY ON THE RELATION OF BARIUM TO THE LOCO-WEED DISEASE.

BY

C. DWIGHT MARSH,
*Physiologist, Drug-Plant, Poisonous-Plant, Physiological,
and Fermentation Investigations.*

II.—LABORATORY STUDIES ON THE RELATION OF BARIUM TO THE LOCO-WEED DISEASE.

BY

C. L. ALSBERG AND O. F. BLACK,
*Chemical Biologists, Drug-Plant, Poisonous-Plant, Physiological,
and Fermentation Investigations.*

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 15, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 246 of the series of this Bureau the accompanying manuscript, entitled "The Relation of Barium to the Loco-Weed Disease." The manuscript consists of two separate contributions to the knowledge of the loco-weed disease, written from different standpoints: (1) "A Field Study on the Relation of Barium to the Loco-Weed Disease," by Dr. C. Dwight Marsh, Physiologist, and (2) "Laboratory Studies on the Relation of Barium to the Loco-Weed Disease," by Dr. C. L. Alsberg and Mr. O. F. Black, Chemical Biologists.

These investigations were carried out in the Office of Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations under the direction of Dr. Rodney H. True, Physiologist in Charge. The first paper constitutes a contribution to the study of the loco-weed problem as encountered by stockmen in many of the grazing States of the West; the second paper presents evidence gained through the help of the laboratory. In this connection, information obtained from the barium-bearing regions in Virginia is used to shed light on the situation. A full bibliography of barium poisoning, prepared in connection with the first paper, is kept on file for future reference.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—781.

THE RELATION OF BARIUM TO THE LOCO-WEED DISEASE.

I.—A FIELD STUDY ON THE RELATION OF BARIUM TO THE LOCO-WEED DISEASE.

By C. Dwight Marsh, *Physiologist, Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.*

INTRODUCTION.

The work of Dr. Albert C. Crawford,[1] formerly Pharmacologist in the Bureau of Plant Industry, in determining the presence of barium in loco weeds and his conclusions that, at Hugo, Colo., at least, the inorganic constituents, especially barium, are responsible for the symptoms of loco poisoning gave a logical basis for experimental work on antidotes. Inasmuch as his work was carried out under laboratory conditions and on animals different from those that commonly suffer from loco poisoning, it was necessary for the confirmation of his results to make feeding experiments with barium on cattle and horses under range conditions. This report deals with those two phases of the field work of 1908.

In order that an antidote may be of practical use it must be cheap and must be capable of being administered in such a way as to meet the conditions of range animals. Anything like individual treatment is, of course, impracticable. The question was naturally raised whether an antidote could not be given in water or in salt. In a large part of the West animals are watered at definite places, and it would be possible to apply a cheap antidote through the water, if such an antidote could be found, and thus counteract the effects of the poison; or, if it were possible to mix the antidote with salt, it is evident that it could be so administered.

AMOUNT OF BARIUM TAKEN IN DAILY DOSES IN LOCO FEEDING.

In order to compute the amount of antidote necessary it is important to have at least an approximate idea of the quantity of barium that an animal will get in an average day's feeding of loco. Crawford bases his estimate of the amount of barium ingested daily on the assumption that the daily ration of grass is 60 pounds.[1] Other authors than those quoted by him make the daily ration much less. For example, Jordan[2] states that the maintenance ration of mixed hay for bovines is 15.5 pounds per day. It is very difficult to find authoritative statements in regard to the quantity of grass eaten daily by the average horse or steer. Jordan's estimate has been considered by the writer as a minimum and Crawford's as a maximum, and the experimental work was carried out on the basis of both estimates. Using Jordan's estimate, if it is assumed that the grass of the western plains weighs twice as much as hay, the daily ration of grass is about 30 pounds. As range animals feed on comparatively dry grasses, this is probably an overestimate. It is impossible to say what proportion of this daily ration would be loco. Post-mortems show that all loco eaters take a large proportion of other food. It is rarely true that an animal eats loco exclusively. Chronic cases gradually eat less and less until they starve to death. Hence, the assumption that half of the daily food is loco would doubtless be a large overestimate. On the basis of a daily ration of 30 pounds, assuming that half of the food is loco, an animal would eat 15 pounds, or about 8 kilograms, of the weed daily. Crawford estimates[3] that 12.44 per cent of the dried plant is ash[4] and in this ash 1 gram has 0.0026 of barium sulphate.

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[1] Crawford, A. C. Barium, a Cause of the Loco-Weed Disease. Bulletin 129, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908, p. 75.

Assuming that an animal will eat as much as 8 kilograms (17.64 pounds) of loco daily, this would be equivalent to a little over 5 kilograms (11 pounds) of dry material, inasmuch as loco on the average loses about one-third when drying in the air, and 12.44 per cent of these 5 kilograms would be the ash in the daily food. Calling it for the sake of round numbers 12.5 per cent, the ash in the daily food would be about 625 grams. Inasmuch as there is 0.0026 gram of barium salts in 1 gram of the ash, the daily feed of loco would contain 1.625 grams of barium salts. If, on the other hand, Crawford's estimate of the daily ration is taken and the assumption is made that an animal on a full daily diet of loco would get about 10 grams of barium salts and if one assumes that of this daily diet half is loco, the animal would then get 5 grams of barium salts daily. In arranging for the experiment, therefore, on the basis of Crawford's analyses, it appears that one might assume that an animal would get in its diet a maximum daily allowance of barium salts of 2 to 5 grams.

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[1] Crawford, A. C. Op. cit., p. 74.

[2] Jordan, W. H. The Feeding of Animals, 2d ed., New York, 1903, p. 299.

[3] Crawford, A. C. Op. cit., p. 75.

[4] The loco weed used in these series of experiments was *Aragallus lamberti*, all gathered near Hugo, Colo.

ANTIDOTES USED.

Magnesium sulphate was the substance naturally thought of as an antidote, as it is a recognized remedy for barium poisoning, is easily obtained, and is cheap. Consequently the experiment was mainly in the use of this substance. It was thought best also to try sulphuric acid, as it, too, would be a logical antidote and is cheap.

POSSIBILITY OF GIVING ANTIDOTES IN SALT.

Horses upon the plains of Colorado eat so little salt that it is evident that an antidotal effect would not be assured by mixing Epsom salts with their salt. In regard to cattle, Henry states that a steer or cow takes about 1 ounce of salt daily. An ounce avoirdupois is equal to 28.297 grams. If it is assumed that an equal amount of a sulphate, like magnesium sulphate, will serve as an antidote for the barium and an attempt is made to furnish an antidote with the salt there should be added to the salt one-fifth of its weight of the sulphate.

Epsom salts are quite distasteful to cattle and it was evident from the outset that to make them eat salt in which was mixed as much as one-fifth of its weight of Epsom salts would be impossible. So it was definitely decided early in the experiment that it was impossible to administer the antidote in the salt. Even if the lower estimate of the daily ration were used, assuming that half of this were loco, the animal would get a quantity of barium that would require for its neutralization 1.5 grams of Epsom salts; or, one-twentieth of the salt would have to be Epsom salts. This proportion was found to be impracticable.

POSSIBILITY OF ADMINISTERING ANTIDOTES IN WATER.

Assuming that an animal drinks 70 pounds of water daily, or 35 kilograms, on the basis of 8 kilograms of loco daily the amount of magnesium sulphate in the water would have to be in the ratio of 1 to 19,500. Or, using Crawford's estimate of the amount that an animal may eat daily and assuming that a steer gets as much as 5 grams of the barium salts, it follows that the animal would have to receive about an equal quantity of the antidote, and to obtain this amount the ratio of the magnesium sulphate to the water would be about as 1 to 7,000. It was found as a matter of experiment that animals would readily drink water containing magnesium sulphate even when the proportions were quite large. Therefore it seemed to be practicable to administer the antidote in this way.

POSSIBILITY OF USING SULPHURIC ACID AS AN ANTIDOTE.

If it is assumed, as in former estimates, that an animal gets 1.625 grams of barium salts daily, the required antidote would be about 0.773 gram of sulphuric acid. These figures are based on the estimate of a daily ration of 8 kilograms of loco. If Crawford's estimate is taken, the animal would receive 5 grams of barium salts daily. To neutralize these salts would require about 2.4 grams of sulphuric acid. It would be entirely practicable to give this or even very much larger doses in the drinking water.

ACTUAL AMOUNT OF BARIUM IN THE LOCO PLANTS FED.

Crawford reports wide variations in the published analyses of loco. Therefore it seemed important to have the loco plants actually used analyzed for their barium content. The plants fed during the summer's experiment were collected from several localities near Hugo, Colo. The analyses made by the Bureau of Chemistry are shown in Table I.

TABLE I.—*Amount of barium in loco plants used in feeding experiments.*

Plant No.	Ash.	Barium in ash.	Plant No.	Ash.	Barium in ash.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
8.53	42.67	0.023	8.30	22.08	0.106
8.16	21.05	.11	8.15	17.01	.017
8.18	10.78	.088	8.96	29.96	.033
8.29	22.16	.128	8.97	14.60	.0683

It would appear from Table I that the average ash content of these loco plants was 22.54 per cent and that the average percentage of barium in the ash was 0.0717. Computed in a form showing the amount of barium salts in air-dried loco, it is seen that 1 gram of air-dried loco contains an equivalent of 0.00027 gram of $BaSO_4$, or 0.00029 gram of $BaCl_2+2H_2O$, or 0.00032 gram of $Ba(C_2H_3O_2)_2+H_2O$.

It was found as a matter of experiment that on the average the loco plants used in Hugo lost one-third in drying in the air. It would appear, therefore, that 1 gram of fresh loco would contain 0.00018 gram of $BaSO_4$, or 0.00019 gram of $BaCl_2+2H_2O$, or 0.00021 gram of $Ba(C_2H_8O_2)_2+H_2O$.

On the basis of a daily ration of 8 kilograms of fresh loco an animal would get 1.44 grams of $BaSO_4$, or 1.52 grams of $BaCl_2+2H_2O$, or 1.68 grams of $Ba(C_2H_8O_2)_2+H_2O$. If it ate, according to Crawford, 30 kilograms daily, it would get an equivalent of 5.4 grams of $BaSO_4$, or 5.7 grams of $BaCl_2+2H_2O$, or 6.3 grams of $Ba(C_2H_8O_2)_2+H_2O$. It would appear from these figures that in the actual experiment, if the lower estimate of the daily ration of fresh loco is used, the animal would consume not over 2 grams of barium salts. If Crawford's estimate of the daily ration is used and it is assumed that half the daily ration is loco, the amount of barium salts daily ingested would be between 3 and 4 grams. While, therefore, the experiment was started with considerable uncertainty with regard to the actual amount of barium salts concerned, it would appear from the results of these analyses that the actual course of the investigation would have been very nearly the same if the amount of barium in the loco plants which were fed had been known at the beginning of the season.

OUTLINE OF EXPERIMENTS ON ANTIDOTES.

In order to control the drinking water, a well was sunk in one of the pastures and the animals were held in such a way that all their water must come from this well. It was planned to pasture a certain number of animals upon loco; to feed definite amounts of weighed loco to others and water some of them at the well with water in which magnesium sulphate had been dissolved; to treat the water for others with sulphuric acid, and also to maintain as a control one or more animals treated with unmedicated water.

The estimates of the amounts of magnesium sulphate and of sulphuric acid necessary were in the first place based upon the assumption that the quantity of sulphates in the water could be ignored. Analyses, however, were made both of the well water and of the water in the creek at which the pastured animals were watered in order to find out the amount of sulphates in those waters. The returns from these analyses, which were made in the Bureau of Chemistry, eventually modified very materially the amount of Epsom salts and sulphuric acid used for antidotal purposes. Hence, in the latter part of the time during which the experiment was conducted, the quantities of magnesium sulphate and sulphuric acid in the water were increased very nearly to the maximum which the animals would take. Care was exercised, of course, that the amount of magnesium sulphate taken should not serve as a physic, but very little trouble was experienced from this source. It was found that the animals would readily drink water with the larger quantity of magnesium sulphate but that they would less readily drink water which was made distinctly acid by sulphuric acid. Crawford[1] has noted the possibility that alkaline bicarbonates in the stomach, which may have been derived from the drinking water, might interfere with the precipitation of barium by the sulphates. This possibility was recognized in the Hugo experiments, but it was assumed that whatever effect the alkaline bicarbonates might have would modify the solubility in only a slight degree and might be ignored in a series of experiments which could not in any case be exact.

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[1] Crawford, A. C. Op. cit., p. 71.

EXPERIMENTS WITH MAGNESIUM SULPHATE.

On Crawford's estimate that 12.44 per cent of dried loco plant is ash and that this ash has an equivalent of 0.0026 gram of barium sulphate to 1 gram, if it is assumed that an animal eats 8 kilograms of loco daily, the daily feed of loco would contain about 1.6 grams of barium sulphate. This will require rather more than an equal amount of magnesium sulphate to serve as an antidote, or, putting it in round numbers, about 2 grams of magnesium sulphate would be necessary to serve as an antidote to the barium ingested daily. If, on the other hand, use is made of Crawford's estimate that an animal on a full daily diet of loco would get about 10 grams of barium salts presumably calculated as the sulphate, then, on the assumption that half the diet is loco, it would get about 5 grams of barium sulphate. This would take slightly more than 5 grams of magnesium sulphate as an antidote. On this basis it was assumed that in all probability 2 to 3 grams of magnesium sulphate daily would be sufficient to neutralize the probable amount of barium which was taken in connection with the loco feeding.

The experiments were commenced by adding 10 grams of magnesium sulphate to 100 liters (105.7 quarts) of water. On the basis that each animal drinks 25 liters (26.4 quarts), this would give 2.5 grams of the sulphate for each animal. As has been stated before, however, the results of the analysis of water showed that the natural waters near Hugo contain a large percentage of sulphates. On the assumption that an animal drinks 25 liters of water daily, it would follow that inasmuch as the analysis shows that 1 liter (1.057 quarts) of the well water contains 0.3876 of SO_4, 25 liters would contain 9.69 grams of SO_4. As 9.69 grams of SO_4 is about equivalent to 25 grams of magnesium sulphate, an animal drinking well water would get the equivalent of 25 grams of Epsom salts daily; or, if it should drink the creek water, it would get 1.65 times as much. Inasmuch as it was known that animals pasturing in the neighborhood of the creek became locoed, it would follow that if the water contained from 40 to 50 grams of magnesium sulphate it would not serve as an antidote. It was evident that if magnesium sulphate was to be used as an antidote, each animal must get something more than 50 grams per day. Because of this fact it seemed desirable to increase the magnesium sulphate to an amount as great as the animal could bear without injury.

The experiment finally was conducted in the following manner: From May 25 to June 1, 10 grams were used to 100 liters of water; from June 2 to 26, 275 grams were used to 100 liters of water; from June 27 to the end of the season, 300 grams were used to 100 liters of water. This last amount evidently would give about 75 grams to each animal, or including the quantity in the water each animal would get about 100 grams daily. It was found as a matter of experiment that the animals drank the water quite readily, and this experiment was carried on through the season with only a few interruptions on occasions when the animals managed to break through fences and drink creek water.

Four animals were treated in this way, as follows:

Cow No. 35 was treated from May 25 to August 19, eating on the average about 5 pounds daily of green loco. This animal showed distinct symptoms of loco poisoning on August 11, and the experiment was discontinued on August 19.

Steer No. 6 was fed from May 25 to August 31, having a daily ration of about 10 pounds of green loco. This animal was distinctly locoed August 3, and the experiment was discontinued on August 31.

Cow No. 84 was fed from May 25 to September 5. She took on an average about 10 pounds of green loco daily and was distinctly locoed on September 3. This experiment was discontinued on September 5.

Horse No. 57 was an animal which had been partially locoed in 1907, but was improved at the end of that season and did not show many symptoms of loco poisoning in the spring of 1908. This horse was fed from May 27 to August 12, receiving an average of about 8 pounds of green loco daily. It was distinctly locoed on July 29 and died on August 18.

All of these animals were first placed in the corrals and starved for a day or two in order to induce them to eat loco. As soon as the habit was partially formed they were kept in the pasture by day and brought back into the corrals at night, the plan being to give them their feeding of loco at night. If they did not eat readily they were taken out somewhat later in the morning in order to starve them into their doses.

The animals were watered together, so that the amount of magnesium sulphate taken by any animal would depend upon the quantity of water which it drank. In the course of the experiment, however, they averaged pretty close to the estimated amount of 25 liters daily.

It will thus be seen that of the animals which were treated with magnesium sulphate, all became locoed.

EXPERIMENTS WITH SULPHURIC ACID.

Basing the work with sulphuric acid on the same figures as in the case of magnesium sulphate, it would appear that an equivalent of 100 grams of magnesium sulphate could be obtained by using 39 grams of SO_4, or, assuming that each animal drinks 25 liters daily, 156 grams per 100 liters of water. Inasmuch as the well water contains an equivalent of 38.76 grams of SO_4 per 100 liters, in order to get the full equivalent of 100 grams of magnesium sulphate each it would be necessary to add to the water 117.24 grams of SO_4, or approximately 120 grams of sulphuric acid for every 100 liters. This would be the equivalent of about 66.6 cubic centimeters of the commercial sulphuric acid.

In starting the experiment on June 6 the proportion of sulphuric acid used was 75 cubic centimeters to 100 liters of water. The animals did not drink this proportion readily, so it was reduced somewhat. On June 7, 50 cubic centimeters of sulphuric acid was used to 100 liters of water; from June 14 to 19, 40 cubic centimeters to 100 liters; from June 20 to July 9, 25 cubic centimeters to 100 liters; from July 10 to September 17, 50 cubic centimeters to 100 liters. The reduction in the proportion of sulphuric acid during the intermediate part of the experiment was because most of the animals did not drink the water freely, as the quantity used made the water very distinctly acid, and it was evidently distasteful to them; but as the season progressed, as would be expected, they took the water more freely, and it was found possible to increase the proportion to some extent.

Five animals were fed on measured rations of loco, as in the magnesium sulphate experiments, and watered with the acidulated water, as follows:

Cow No. 31 from June 5 to September 17 received a daily ration averaging between 2 and 3 pounds of green loco, but as a matter of fact she ate very much less, as she refused to eat so large an amount of the weed. She was not affected by the loco.

Steer No. 41 was fed from June 4 to September 25, averaging about 6 pounds of green loco daily. At the end of the experimental period he was in good condition, but showed slight symptoms of loco poisoning.

Bull No. 68 had been partially locoed in 1907, but was in good condition in the spring of 1908. He was fed from June 4 to September 25 an average of 7 pounds of green loco daily. He drank the acidulated water very freely and became distinctly locoed.

Horse No. 55 was fed from May 27 to August 15, receiving an average of about 8 pounds of green loco daily. This animal was started on a mixture of salt and magnesium sulphate, but when that was found impossible, was put with the sulphuric-acid group and received acidulated water from June 6 until the time of death. She was distinctly locoed on August 6 and died August 25.

Cow No. 82 was fed from May 27 to September 25 an average of about 4 pounds of green loco daily. She was watered at the well until

June 6, and from that date received acidulated water. She did not take the loco with great freedom and proved to be an animal somewhat difficult to manage, as she frequently broke through the fence and drank a great deal of water at the creek. She was not affected by loco poisoning.

Of the five animals which were fed upon measured portions of loco and watered with sulphuric-acid water, three became distinctly locoed. If we disregard cow No. 31, as could reasonably be done, inasmuch as she took practically no loco, the result would be that three out of four became locoed.

In addition to the animals which received a measured ration of loco daily, four animals were pastured upon loco and watered at the same time as the preceding group upon water acidulated with sulphuric acid. These animals were as follows:

Cow No. 30 was pastured from May 27 to September 3, receiving the acidulated water from June 18 to the end of the season. She showed some effect of loco poisoning.

Steer No. 33 was locoed in 1907 and cured without treatment other than careful attention to the food. This animal was pastured and watered as in the case of cow No. 30 and became distinctly locoed.

Steer No. 42, locoed in 1907, was the subject of treatment and was considered entirely cured. He was pastured as in the case of the preceding animals and watered with the acidulated water. He showed distinct signs of loco poisoning on July 31 and died on September 9.

Horse No. 75 was in good condition in 1907; was watered with acidulated water from June 18 to July 19. He became very distinctly a loco subject and was placed upon magnesium-sulphate water from July 20 to 24 with the hope of getting beneficial results. After July 24 the antidote treatment was discontinued.

As in the case of magnesium sulphate, the actual amount of sulphuric acid obtained by each animal varied with the quantity of water it drank. This quantity varied more than in the case of the magnesium-sulphate group. No. 82 drank very little of the acidulated water. Some of the time No. 31 drank very little, so that the average for all the animals would be 15 to 20 liters daily. Taking out Nos. 82 and 31, it is probable that the others would average close to the estimated amount of 25 liters daily.

Of the four animals which were pastured upon loco and treated with acidulated water, three became distinctly locoed.

CONTROL ANIMALS.

Three animals, as in the preceding cases, were fed measured amounts of loco and were watered with untreated well water, as follows.

Steer No. 43 was fed from May 25 to September 23, receiving an average of 5½ pounds of green loco daily. It showed no effect of loco poisoning.

Cow No. 91 was fed from May 25 to September 25, receiving an average of 8 pounds of green loco daily. She was distinctly locoed on September 3.

Horse No. 70 was fed from May 27 to August 17, receiving an average of 8 pounds of green loco daily. She became locoed on August 10.

Besides these animals, four were pastured and watered at the well, as in the case of the preceding group.

Cow No. 90 was pastured from May 27 to September 23, receiving creek water up to June 18 and well water from that time on. It was not locoed.

Steer No. 1 was similarly pastured and was not affected by loco poisoning.

Horse No. 72 was pastured from May 27 to July 23, being watered as in the preceding cases, and was distinctly locoed July 20.

It will be seen that of the seven control animals, three receiving a measured ration of loco and four being pastured, three became locoed. In other words, it appears that the animals treated with an antidote became locoed more readily, if anything, than those that received no such treatment.

SUMMARY OF RESULTS IN ANTIDOTE WORK.

(1) Granted that barium is the substance producing the symptoms of loco poisoning, the indicated antidotal treatment is the use of the sulphates in some form. Epsom salts is the substance that would most naturally be used, while sulphuric acid would theoretically be just as efficient.

(2) Theoretically, a daily dose of 2 to 5 grams of Epsom salts or of not to exceed 2 grams of concentrated sulphuric acid should be ample to serve as an antidote to the amount of barium ingested in loco feeding upon the range.

(3) Inasmuch as the natural waters where the animals became locoed contain in salts an equivalent of something more than 40 grams of magnesium sulphate in the daily quantity ordinarily drunk by an animal, or something over 12 grams of sulphuric acid, it is evident that more than this proportion must be used to be effective as an antidote, or something over 50 grams of magnesium sulphate or 20 grams of sulphuric acid.

(4) From the results of the experiment it appears that neither magnesium sulphate nor sulphuric acid has any antidotal value in counteracting the effects of loco poisoning.

EXPERIMENTAL FEEDING WITH BARIUM SALTS.

Crawford in his report[1] makes the following statement:

> The main symptoms described in stock on the range can be reproduced on rabbits by feeding extracts of certain loco plants. Those especially referred to here under the term "loco plants," are *Astragalus mollissimus* and *Aragallus lamberti*. * * * The inorganic constituents, especially barium, are responsible for this action, at least in the plants collected at Hugo, Colo. Perhaps in other portions of the country other poisonous principles may be found. A close analogy exists between the clinical symptoms and pathological findings in barium poisoning and those resulting from feeding extracts of certain loco plants. Small doses of barium salts may be administered to rabbits without apparent effect, but suddenly acute symptoms set in analogous to what is reported on the range.

Inasmuch as these experiments had been performed upon rabbits, and the clinical symptoms of loco poisoning had been observed in detail mainly in cattle, horses, and sheep, it seemed necessary, in order to confirm these results and demonstrate that loco poisoning could be produced in cattle, horses, and sheep by barium salts, to make the experiment of feeding barium salts to a number of animals and to have a number of control animals feeding upon loco, making so far as possible the amount of the barium in the two sets of animals equal. In this way it was to be assumed that the symptoms of loco poisoning would be produced in both sets of animals. It may be noted that Crawford[2] states that a part of the barium in the loco plants may not be taken up by the system and that no doubt more of the pure barium salts will be required to produce symptoms of poisoning than would be necessary in the case of the form of barium found in the plant, on the assumption that in the loco weed the barium is better protected from precipitation than are the barium salts when dissolved in water alone.

It seemed wise, then, in making this experiment, to start with amounts of barium salts as nearly as possible equivalent to those which were found in the proportion of loco weed that an animal would be likely to eat in his daily ration. It was planned to continue administering these small doses until symptoms of poisoning appeared. In case these symptoms did not appear it was planned to increase gradually the size of the dose until some positive effect was produced. Inasmuch as a number of animals were at the same time fed upon varying proportions of loco, it was possible, with somewhat large elements of error, to estimate how much barium salts these animals were receiving daily. The comparison of these animals with those which were receiving barium salts should give positive evidence in regard to the identity of loco poisoning and barium poisoning.

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[1] Crawford, A. C. Op. cit., pp. 75–76.

[2] Crawford, A. C. Op. cit., p. 75.

GENERAL PLAN OF THE EXPERIMENTS.

As the result of the preceding work in feeding loco to cattle and horses, it was found that they would become locoed if fed daily from 6 to 16 pounds of the green material; therefore, we may conclude that an average daily ration of 12 pounds (6 kilograms) will produce loco poisoning. It was assumed that the loco was half water. On this basis the animal would get 3 kilograms (6.6 pounds) of dried loco daily. Using Crawford's figures that 12.44 per cent of the dried plant is ash and that there is in each gram of the ash 0.0026 gram of barium calculated as the sulphate, it would follow that the daily feed would contain 0.97032 gram of barium sulphate, or 1.0154 grams of barium chlorid.

It was on this basis that the experiments were started. When it was found as a matter of fact that the loco weeds actually used lost on the average one-third on drying, it followed that the daily dose would be 1.354 grams $BaCl_2+2H_2O$. As has been indicated before, the results of chemical analyses of the loco weeds which were fed during the experiments would not modify these figures materially. Theoretically, the daily administration of between 1 and 2 grams of barium chlorid should result in symptoms of loco poisoning. The possibility must be recognized, however, that many unknown factors in the problem may materially modify this theoretical determination.

DETAILS OF THE EXPERIMENTS.

FEEDING BARIUM SALTS TO CATTLE.

Cow No. 92.—The experiment with cow No. 92 was begun May 30, 1908. From this time to June 10 she received 1.13 grams of barium chlorid daily. This cow would not readily eat grain, so the barium chlorid was fed in solution on a small ration of alfalfa. On some days she may not have received the full dose, as it is possible that she did not eat all of the alfalfa. As a rule, however, most of the barium chlorid must have been taken. From June 11 until July 29 she was given 1.51 grams of barium chlorid daily. After July 29 the barium chlorid was given in bran, as it was found possible to feed her successfully with this form of grain. From August 21 until September 8 she received 10 grams of barium chlorid daily, fed in bran. From September 9 until the end of the experiment on September 26 she received 15 grams daily.

Figure 1 shows that at the beginning of the experiment this cow weighed 1,210 pounds, which increased during the course of the experiment to a maximum of 1,245 pounds on June 11. On July 2 she had fallen to 970 pounds, after which there was an increase, followed by a decrease, and her final weight at the end of the experiment was 970 pounds. During the course of the experiment there were no symptoms of loco poisoning, with the possible exception of the loss in weight, and this may be accounted for by the birth of twin calves and the drain consequent upon nourishing them.

Steer No. 46.—From May 30 until June 10 steer No. 46 was given a daily dose of 1.13 grams of barium chlorid, the salt being fed most of the time in solution on alfalfa. From June 11 to July 21 the daily dose was 1.51 grams of barium chlorid on alfalfa. On two or three days during this time the steer ate none or only a part of its ration, but during most of the time it received nearly the full dose. From July 22 until August 11 it was fed 5 grams of barium chlorid daily on alfalfa. From August 12 to 20 the same dose was given in bran. From August 21 to September 2 it was given 20 grams of barium chlorid daily in bran. From September 3 until September 8 it was given 40 grams daily in bran. From September 9 until September 15 it received 50 grams daily, with the exception of September 11, when it received only 26 grams, and September 12 and 13, when the dose was omitted. From September 16 until the conclusion of the experiment on September 26 it received 60 grams daily of barium chlorid.

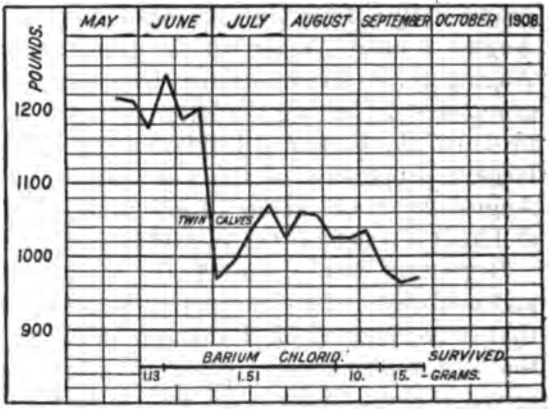

FIG. 1.—Curve of weight of cow No. 92.

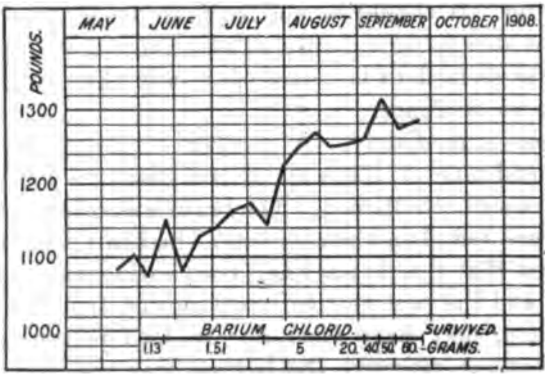

FIG. 2.—Curve of weight of steer No. 46.

From the curve of weight (fig. 2) it will be seen that at the beginning of the experiment this animal weighed 1,105 pounds. At the conclusion of the experiment it weighed 1,285 pounds and was in good condition in every way. No symptoms appeared showing any effect from the barium.

Steer No. 10.—As a result of being fed upon loco in preceding seasons steer No. 10 had been more or less affected by the poisoning, although it was never considered to be distinctly locoed. It was in fair condition when the experiment commenced. From May 30 until June 10 it received 1.13 grams of barium chlorid daily in grain; from June 11 until June 29, 1.51 grams daily; from June 30 until July 6, 3 grams daily; from July 7 until July 13, 6 grams daily; from July 14 to 20, 9 grams daily; from July 21 until July 27, 12 grams daily; from July 28 until August 3, 15 grams daily; from August 4 until August 10, 20 grams daily; from August 11 until August 17, 25 grams daily; from August 18 until August 24, 30 grams daily. During the latter period it did not readily eat the bran in which the barium chlorid was mixed, since it evidently found so large a proportion of the salt distasteful. From August 25 until August 29 it was given 40 grams daily in bran, but because of its dislike it did not eat the full dose on any day.

Beginning with August 30 the barium chlorid was put in solution and administered to the animal as a drench in order to make sure that it received the full amount. From August 30 to September 1 the dose was 40 grams. From September 2 until September 8 it received 45 grams daily. On September 9 and 10 it received 50 grams. During the few days before this dose of 50 grams the animal had appeared to be in somewhat poor condition. On September 9 it seemed to be weak in its hind legs. In attempting to walk up an incline it had great difficulty because of this weakness. Otherwise it acted quite normally. On the morning of September 10 it was unable to use its hind legs sufficiently to get up. It appeared to have very little appetite. About noon it fell over upon its side and died with very little struggling. It should be noticed that the weakness of its hind legs was not due to any paralytic affection. Both the motor and sensory nerves seemed to be functional, only the animal did not have strength to use its limbs.

The autopsy was made immediately. A number of ulcers were found in the mucous membrane on the wall of the fourth stomach and the duodenum was somewhat inflamed. The brain was congested and small blood clots were found in the cavities. The heart was in systole. It is to be noted that this animal had been eating loco for three preceding seasons and the post-mortem appearances, especially the ulcers in the stomach, may have been due to loco poisoning rather than barium poisoning, although the barium was the immediate cause of death. There were no symptoms of barium poisoning preceding the death of the animal except the weakness of the hind legs spoken of and its generally poor appearance in the few days preceding its death.

The weight of this animal (fig. 3) when the barium treatment was commenced was 845 pounds. Near the conclusion of the experiment, on September 3, it weighed 900 pounds. It will be seen that barium poisoning had very little effect in reducing its weight.

Heifer No. 113.—The experiment with heifer No. 113 was commenced on July 21. From July 21 until August 20 she was given 10 grams of barium chlorid daily. During most of this time the salt was fed on alfalfa, although for a few days it was fed in bran. From August 21 until September 5, 20 grams of barium chlorid were given daily in bran. During several days of this period she ate only a part of the dose, the barium chlorid evidently being very distasteful. From September 6 until September 16, with the exception of two days when no salt was available, the 20-gram dose was administered daily as a drench. From September 17 to 24 she received 25 grams daily as a drench.

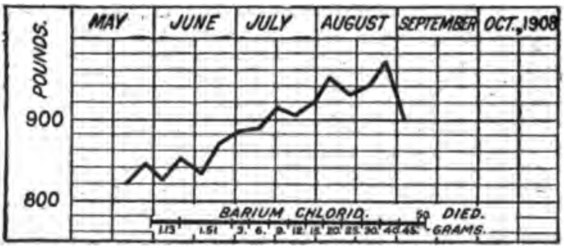

Fig. 3.—Curve of weight of steer No. 10.

At the beginning of the experiment this heifer weighed 415 pounds. Her weight (fig. 4) increased during the experiment, and at the conclusion she weighed 530 pounds; she showed no effects whatever of barium poisoning, unless the drop in weight after September 3 may be attributed to its influence.

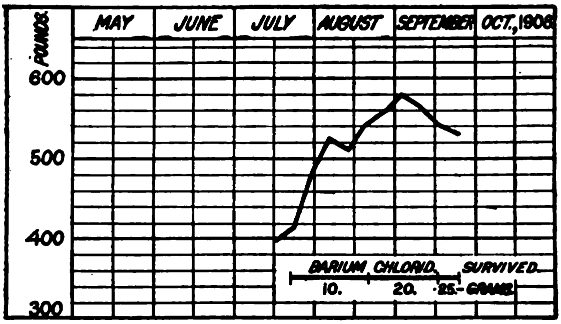

Fig. 4.—Curve of weight of heifer No. 113.

Steer No. 114.—The experiment with steer No. 114 was commenced on July 21. Until August 6 the dose was given on alfalfa, but after that until September 15 in bran. From July 21 until August 20 the animal received 5 grams of barium chlorid daily. From August 21 until September 2 the dose was increased to 10 grams daily. From September 3 until September 8 the dose was 20 grams daily. From September 9 to 18 the dose was 25 grams daily. Inasmuch as the steer failed to eat all the grain because of its dislike of the taste of barium chlorid, from September 15 until September 18 the daily dose of 25 grams was given in solution as a drench.

During this time the animal showed no symptoms of barium poisoning. Its weight (fig. 5) from the beginning of the experiment had increased from 325 to 455 pounds. After receiving the dose of barium chlorid on the morning of September 18 it was driven into pasture with the other animals and appeared entirely well. During that day it was impossible to keep close watch upon the pasture, and the animal was not seen again until between 5 and 6 p. m., when it was found dead. It had fallen and died apparently without a struggle.

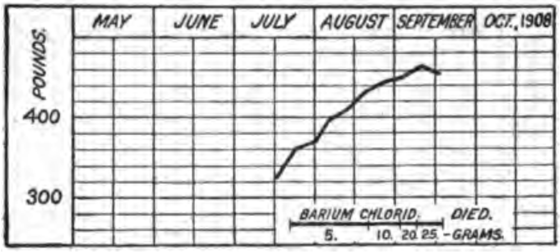

Fig. 5.—Curve of weight of steer No. 114.

An autopsy was made immediately. The heart was found in systole. The mucous membrane of the wall of the fourth stomach was found slightly inflamed. The only noticeable feature of the autopsy was a deeply inflamed condition of the small intestine, indicating very sharp irritation. This was rather striking, inasmuch as there had been no evidence of looseness of the bowels.

Heifer No. 115.—Five grams of barium acetate on alfalfa were fed daily to heifer No. 115 from July 21 to 30. From July 31 until August 20, with the exception of one day when the dose was omitted, she was given 5 grams daily in bran. From August 21 until September 2 she received 10 grams of barium acetate daily in bran. From September 3 until September 14 she was given 20 grams of barium acetate daily in bran. During the last few days of this series of doses the heifer did not eat the bran readily because of her distaste for the barium acetate, so from this time until the completion of the experiment the barium acetate was given in solution as a drench. September 15 and 16 she received 20 grams daily, and from September 17 until the conclusion of the experiment on September 24 she received 25 grams daily.

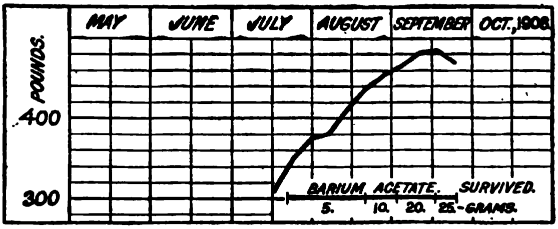

Fig. 6.—Curve of weight of heifer No. 115.

At the beginning of the experiment the heifer weighed 350 pounds, and at the end of the experiment (fig. 6), 470 pounds. The barium administered apparently had no effect upon the animal in any way, either in reduction of weight or in the production of nervous symptoms.

Steer No. 116.—From July 21 until August 7 steer No. 116 received daily 10 grams of barium acetate on alfalfa. On August 8 the dose was omitted. Then the 10-gram dose was continued until August 20, being given during this period in bran. From August 21 until September 2 the dose was increased to 20 grams daily, in bran. From September 3 to September 8 the dose was 30 grams. From September 9 until September 16, with the exception of two days, September 12 and 13, the steer was given 35 grams, the salt being administered in a drench. On September 16 the dose of 35 grams was given about 8.30 a. m. The animal then left the corrals, went out into the pasture, and about 10.30 a. m. was found dead about half a mile from the corrals. It had died apparently without a struggle. There was no evidence that it had moved even a foot after falling to the ground.

An autopsy was made immediately. The mucous membrane lining the wall of the fourth stomach was in part inflamed, with ecchymotic spots at the pyloric end. The inner wall of the duodenum was inflamed and the ileum was deeply inflamed. The mesenteric blood vessels in this case did not appear to be injected, as was true in many other cases.

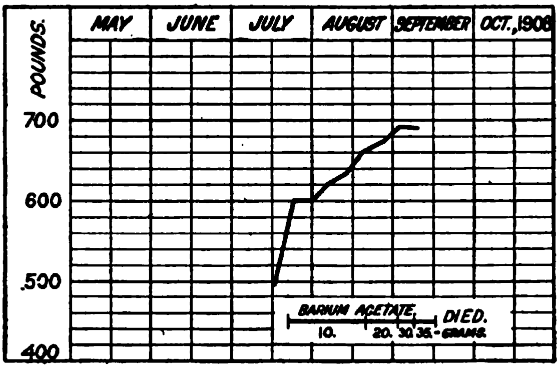

FIG. 7.—Curve of weight of steer No. 116.

This animal weighed at the beginning of the experiment 600 pounds (fig. 7). On September 10, a few days before its death, its weight was 690 pounds. It evidently had not lost weight and there had been no symptoms of poisoning. It had apparently been in entirely good health up to the morning of its death.

Calf No. 109.—Born June 29 of cow No. 92, calf No. 109 was one of a pair of twins. As both were in good condition it was considered that this was a good case for barium feeding, as he could easily be compared with his twin sister, No. 108. From July 22 until August 20, with the exception of one day, when the dose was omitted, he was given 1 gram of barium acetate daily in a drench. From August 21 to September 2 he was given 3 grams of barium acetate daily. From September 3 until September 8 the dose was 5 grams. From September 9 until September 15 he was given 8 grams. September 16, 17, and 18 he received 10 grams daily. During this time he had shown no symptoms of being affected by the poison. After the dose on the morning of September 18 he went into the pasture as usual and was not seen again until in the afternoon, between 5 and 6 o'clock, when he was found dead. He had evidently fallen and died without a struggle.

An autopsy was made on the morning of September 19. During the period of the feeding, the calf had gained weight continuously, its condition comparing very favorably with its twin. In the autopsy the heart was found in systole. The inner wall of the fourth stomach was slightly inflamed. The inner wall of the ileum was deeply inflamed in spots, although the inflammation was not general through the whole length of the small intestine. The brain was congested, and the mesenteric blood vessels were somewhat injected. Figure 8 shows the curve of weight of calf No. 109; also the curve of weight of No. 108 for purposes of comparison.

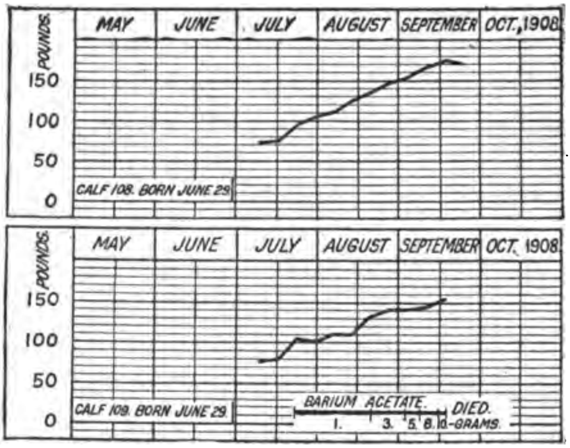

FIG. 8.—Curves of weights of calves Nos. 108 and 109.

Acute barium poisoning of Heifer No. 99.—As will be brought out later, it appeared from the preceding experiments that 1 gram of the barium salt for about 18 pounds of weight proved to be a fatal dose in the cases where the animals were receiving gradually increasing doses. It seemed wise to see what effect this amount of barium would have if given immediately to an animal without any preceding course of small doses.

Heifer No. 99 was a strong, healthy animal, thought to be a good subject for such an experiment. On September 20 she was given 22 grams of barium acetate as a drench. No effects were noticed. The next day she was given the same amount. She died about 5.30 p. m. Just before this time she was found lying on her belly, with her legs doubled up under her and her head thrown down on the ground to one side. She acted as though in pain, although she did not struggle. Passages from the bowels covered with mucus indicated an inflamed condition of the intestines. Death occurred a few minutes after she was found in this position. At about 2.30 p. m. she had been noticed lying down not far from the location in which she died, but apparently she was all right at that time.

An autopsy was made on the morning of September 22. It was noticed that the superficial blood vessels of the heart were injected and the inner walls of both auricles and ventricles were deeply inflamed. The walls of the second and fourth stomachs were deeply inflamed, and the leaves of the third stomach were infiltrated with inflamed spots, nearly the whole surface being reddened. The whole small intestine was very deeply inflamed and the cæcum slightly so. It was evident that the barium poisoning had produced profound inflammation of the alimentary canal. Apparently death had resulted from the effect upon the circulatory and respiratory systems. Figure 9 shows the curve of weight of the animal.

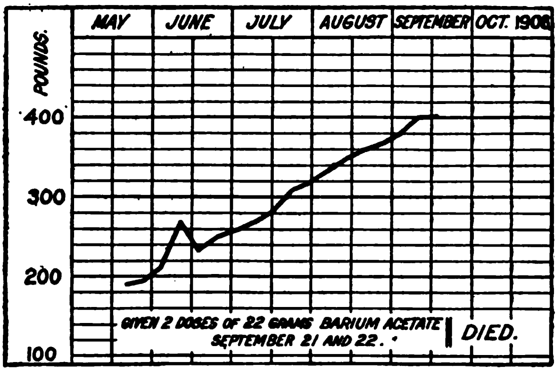

FIG. 9.—Curve of weight of heifer No. 99.

FEEDING BARIUM SALTS TO HORSES.

Horse No. 62.—Horse No. 62 had been fed loco in preceding seasons, but had never shown signs of being seriously affected by poisoning. He was given barium chlorid in grain from May 30 to September 24. From May 30 to June 10 he was fed 1.13 grams of barium chlorid daily; from June 11 to July 21, 1.51 grams; from July 22 until September 2, 10 grams; from September 3 until September 8, 15 grams; from September 9 until September 16, except on September 12 and 13, 20 grams; and from September 17 until the conclusion of the experiment on September 24 he received 30 grams of barium chlorid daily.

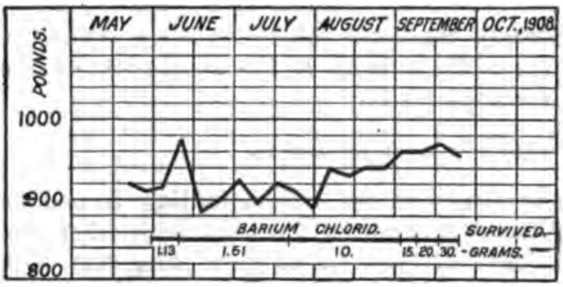

FIG 10.—Curve of weight of horse No. 62.

At the beginning of the experiment this horse weighed 910 pounds, and at the conclusion of the experiment 955 pounds (fig. 10).

He was in remarkably good condition during the whole summer, his coat being smooth and silky—in fact there was no better looking horse on the ranch. There was no symptom of any effect from the doses given.

Horse No. 61.—Horse No. 61 had never been fed on loco at the time the experiment was commenced. Although he was an old horse, he was in thoroughly good condition and was considered a good animal for such an experiment. From July 22 until September 2 he was fed 10 grams of barium acetate daily. This was fed most of the time in bran or chop, inasmuch as he ate grain very freely. The dose was omitted during this period on only two days. From September 3 until September 8 he was fed 15 grams of barium acetate daily. From September 9 until September 16 the dose was increased to 20 grams. From September 17 until the conclusion of the experiment on September 24 he was fed 35 grams of barium acetate daily.

At the beginning of the experiment this horse weighed 825 pounds (fig. 11). At the conclusion of the experiment he weighed 830 pounds. The weight had continued pretty nearly uniform during this time. Inasmuch as he was an old animal in good condition when the experiment started, under normal conditions we could expect his weight to remain nearly constant. There were no symptoms whatever of poisoning and the animal at the conclusion of the experiment was in fine condition.

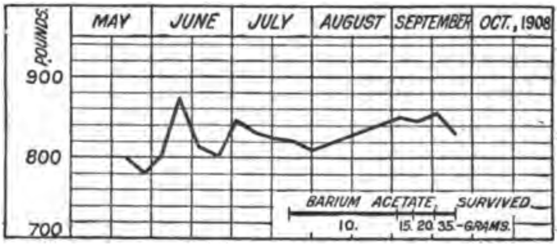

FIG. 11.—Curve of weight of horse No. 61.

EXPERIMENTAL WORK ON RABBITS.

It seemed best, in connection with the barium feeding, to make a few experiments on rabbits as a check on the work with other animals. Loco (*Aragallus lamberti*) was fed to six rabbits, Nos. 3, 7, 8, 10, 11, and 12. The plan was to make the full feeding of loco, but as the experiment progressed it was found that the rabbits did not have sufficient appetite for the weed to eat any very large amount, although very little other food was supplied them. They were fed through periods varying from a few days to something over a month.

Rabbit No. 3 was fed from August 29 to September 28, the quantity received varying from 100 to 200 grams daily. It showed no symptoms of poisoning, and the fact that its weight remained constant showed that it did not suffer from starvation.

Rabbit No. 7 was fed for three days, when it died. It was troubled with diarrhea and its death was evidently caused by something else than loco.

Rabbit No. 8 was fed for eight days but refused to eat much of the loco, and the experiment had to be given up for fear of starvation.

Rabbit No. 10 was fed 100 to 200 grams daily from September 4 until September 28. It showed no symptoms of loco poisoning, but exhibited a marked loss in weight, falling from about 2,300 to 1,650 grams.

Rabbit No. 11 was fed loco from September 1 until September 28, receiving from 100 to 200 grams daily. It decreased in weight from about 1,950 to 1,750 grams, but showed no starvation symptoms. No symptoms of loco poisoning appeared.

Rabbit No. 12 died after about four days' feeding, of acute inflammation of the cæcum. Death was evidently due to an acute infection and was not connected in any way with loco.

The feeding of loco was entirely inconclusive, and it is to be presumed that none of the animals received enough of the poison to produce the characteristic symptoms.

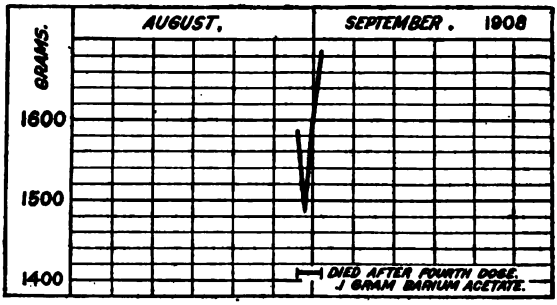

FIG. 12.—Curve of weight of rabbit No. 1.

Barium salts were fed to five rabbits, Nos. 1, 2, 4, 5, and 9. The salts were administered in solution through a stomach tube, and No. 6 was given an equal dose of water daily as a control.

Rabbit No. 1 received four daily doses of 0.1 gram of barium acetate. About 15 minutes after receiving the fourth dose, the animal was found lying with its hind legs motionless and moving its fore legs but very little. It gasped, its respirations and heart action were very rapid, and in about half an hour after the administration of the dose it was dead. The condition of the hind legs was not strictly that of paralysis, but rather that of weakness, as it had possibilities of both sensation and motion. An autopsy was made immediately. The mesenteric blood vessels were found very much congested. No other characteristic symptoms of poisoning appeared. During the feeding of barium this rabbit increased in weight (see fig. 12), so that there was no question of starvation.

Rabbit No. 2 received six daily doses of 0.1 gram of barium acetate, but showed no symptoms of poisoning until the sixth dose. This was administered about 10.30 a. m. Immediately after, the rabbit fell on its side with apparent symptoms of partial paralysis, the hind limbs being more affected than the fore limbs. On stimulation, however, it was found that the limbs were not paralyzed. It gasped, had violent convulsions, and died at 10.40. In the autopsy the walls of the stomach were found inflamed. The inner wall of the duodenum was inflamed, the mesenteric blood vessels were congested, and the spinal cord and brain were congested. There were blood clots in the epidural space of the spinal column. Rabbit No. 2 gained rapidly in weight during the period of the administration of barium. Figure 13 shows the curve of weight during the experiment.

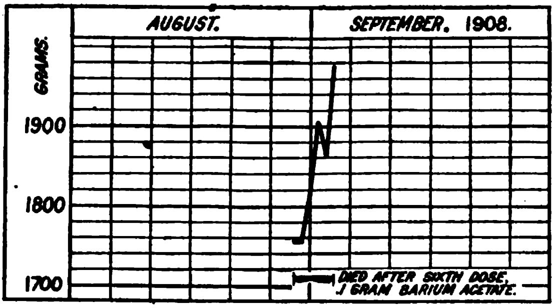

FIG. 13.—Curve of weight of rabbit No. 2.

Rabbit No. 4 was fed barium acetate from August 29 until September 13. From August 29 until September 8 it received daily doses of 0.05 gram; after that 0.075 gram daily. During this period it gained in weight from 1,566 grams to 1,846 grams (fig. 14) and apparently was entirely healthy, showing no symptoms of poisoning. A few minutes after receiving its dose of 0.075 gram on September 13 it was stretched out on its belly, gasping. It did not appear extremely weak and when startled would move about readily. It apparently gradually recovered and was put in the pen. The dose was given between 10 and 10.15 a. m.; by 10.45 it was found on its side in the pen with its hind legs motionless. Respiration was about 120, the temperature was 103.6, and the heartbeats were extremely rapid. At 11.35 it was able to kick with its hind legs, showing that there was nothing like complete paralysis. It lay upon its belly with its head erect. Respiration at this time was 120. At 12 o'clock on being stimulated it

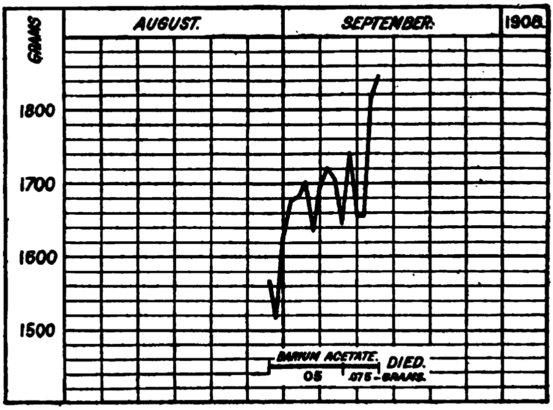

FIG. 14.—Curve of weight of rabbit No. 4.

brought up its hind legs under it, sat up, and jumped off, but moved somewhat awkwardly and made only two or three jumps. As it sat up it acted a little sleepy. It was left at 12.15 and was found dead at 12.30. In the autopsy a few blood clots were found in the lungs. That some water had passed into the larynx in the process of dosing seemed probable and perhaps the effect of the barium poisoning was thus complicated. The mesenteric blood vessels were injected, the cardiac portion of the stomach was inflamed in its inner wall, and there were patches of extravasated blood. The inner walls of the small intestines were inflamed. It was noticed in this animal, too, that the cystic veins were injected.

Rabbit No. 5 was fed barium salts from August 29 to September 28. From August 29 to September 8 it received 0.05 gram of barium acetate daily; from September 9 to September 17, 0.075 gram daily; from September 18 until September 26, 0.1 gram daily. On September 27 it was given 0.12 gram and on September 28, 0.15 gram. During this period it increased in weight from 1,676 to 2,362 grams (fig. 15) and showed no symptoms of any effect from the barium.

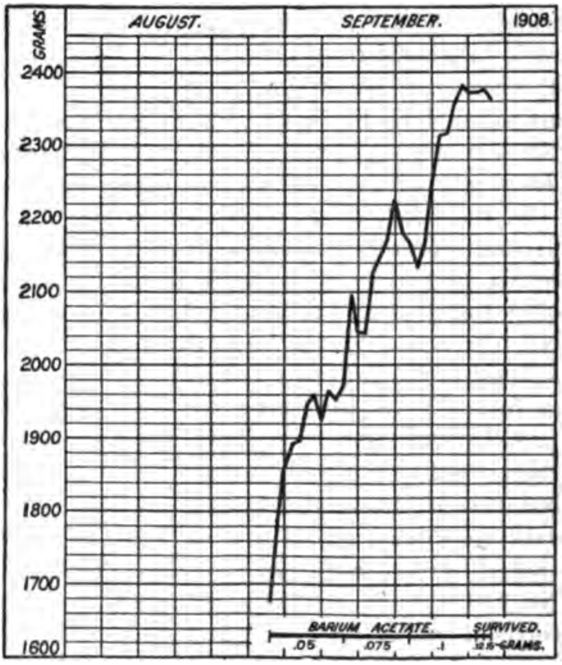

FIG. 15.—Curve of weight of rabbit No. 5.

Rabbit No. 9 weighed 2,076 grams. It was given two doses of 0.2 gram of barium acetate on September 1 and 2. After the second dose, which was given in the morning, it appeared to be all right, but at 6 p. m. it was found lying on its side with its hind legs extended and motionless. The heartbeats were from 160 to 190 per minute. It was visited again at 6.45. While it was being watched it developed convulsive movements of the head, forelegs, and tail. It was seen again at 7.15; the convulsive movements were continued. It died during the night. In the autopsy the heart was found in systole, the mesenteric blood vessels were congested, inflamed areas were found in the walls of the stomach, and slight evidence of inflammation in the walls of the duodenum. The brain was considerably congested and considerable blood was found in the epidural space of the spinal cord. This was evidently a case of acute barium poisoning.

DISCUSSION OF THE EXPERIMENTAL FEEDING OF BARIUM.

RELATION OF LETHAL DOSE TO WEIGHT.

In connection with the question of the cumulative effect of barium poisoning it is of interest to note how much of the barium salts was taken before the effects of poisoning appeared. In the rabbits which died this varied from 0.4 gram to 0.925 gram, or in terms of ratio to weight from 1:1,816 to 1:5,145. With the exception of No. 4, which was fed barium acetate from August 29 to September 13, all the rabbits died after receiving from 4 to 6 daily doses. Rabbit No. 5 received a total of 2.445 grams of barium acetate in 30 daily doses, receiving 1/1,031 of its weight without any effect whatever.

In the cattle that succumbed to the poison the total amount of barium salts received varied from 44 grams in No. 99 to 1,437 grams in No. 10. It should be noted in this connection that No. 10 was the only full-grown animal in the number and that the amount which No. 99 received was given in two daily doses. The ratio of the total amount of barium salts received to the weight in the fatal cases was as follows: No. 10, 1:313; No. 114, 1:367; No. 116, 1:316; No. 99, 1:4,545; No. 109, 1:344. If we eliminate the acute case, No. 99, there would seem to be a fair degree of uniformity in these ratios, but this uniformity disappears when we compare them with the ratio of those animals that suffered no harm from the administration of barium salts: No. 46, 1:327; No. 92, 1:1,091; No. 115, 1:286; No. 113, 1:258; No. 61, 1:642; and No. 62, 1:768. As No. 115 received 1/286 of its weight and No. 113 received 1/258, more than in any of the fatal cases, it would appear that no definite limit can be assigned as the total which an animal may receive, and that, presumably, small doses might be taken almost indefinitely without any bad effects.

LETHAL DOSE.

Crawford has discussed the literature of barium poisoning in rabbits and has made a considerable number of experiments bearing upon the question of the lethal dose in these animals; so it is not necessary to discuss the matter here, as the additional experiments were few in number. Doses of 0.075 to 0.1 gram ordinarily proved fatal. The ratio of dose to weight which finally proved fatal varied from 1:1,029 to 1:22,400, while No. 5 received 1/16,800 of its weight with no ill effects.

These results correspond fairly well to those reported by Crawford and preceding authors. A wide limit of variation is evident. It would appear that doses above 0.5 gram in rabbits of average size may give fatal results. Generally speaking, rabbits are much more susceptible to barium poisoning than are horses and cattle.

Very little seems to have been published in regard to the lethal dose of barium for horses and cattle given per os. Huzard and Biron are quoted by Christison[1] as having killed a horse in 15 days by daily doses of 8 grams of $BaCl_2$, with no symptoms previous to death. Dieckerhoff[2] states that a dose of 8 to 12 grams of $BaCl_2$ is dangerous to a horse and that a 2-year-old heifer received 40 grams with no effect. Reynolds[3] killed a horse with 15 grams of $BaCl_2$.

Granting that toleration is not acquired (and these experiments show little evidence of it), the lethal dose for horses and cattle appears, in these cases, to be considerably higher than the previously recorded results would lead one to expect. Horse No. 61 received 35 grams and horse No. 62 received 30 grams with no ill effects. No. 61 averaged about 850 pounds in weight and No. 62 about 950 pounds. One received 1/12,143 of its weight and the other 1/15,833 of its weight with no bad results; this is three times the dose which Dieckerhoff considers dangerous. The actual lethal dose for horses was not determined.

On the basis of a 1,000-pound animal it would appear from these results that the lethal dose for cattle is something over 50 grams. The smallest dose which produced death in the case of cattle was at the rate of 55 grams per 1,000 pounds of weight. Even this did not in all cases produce evidences of poisoning, for No. 115 received 62.5 grams per 1,000 pounds of weight without any symptoms of poisoning. In general it can be said, however, that the danger limit per 1,000 pounds of weight is reached when the dose exceeds about 50 grams. With cattle the ratio of fatal dose varied from 1:6,500 to 1:9,000, averaging 1:8,232, or, in other words, 1 gram to about 18 pounds of weight proved fatal when repeated two or three times. In two cases only did cattle receive such large doses and live. No. 115 received for 8 days a dose equal to 1/8,000 of its weight without any bad results. No. 109 received 1/8,125 of its weight for 7 days, and only succumbed after three doses of 1/6,500 of its weight. The experiment would seem to indicate that the danger line lies in a dose of about 1/8,000 of the animal's weight, but with considerable possibility of variation, due in part, probably, to the individual peculiarities of the animal. It may succumb to a dose of 1/9,000, or it may endure a dose of 1/6,500 or of 1/7,000 of its weight. There appears to be no appreciable difference in the toxic effect of the two salts, barium chlorid and barium acetate.

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[1] Christison, R. Treatise on Poisons. Edinburgh, 1845, p. 578.

[2] Dieckerhoff, W. Ueber die Wirkung des Chlorbaryum bei Pferden, Rindern, und Schafen. Berliner Thierärztliche Wochenschrift, 1895, p. 265.

[3] Reynolds, M. H. A Study of Certain Cathartics. Fifteenth Annual Report, Minnesota Agricultural Experiment Station, 1907, pp. xxi–xlii.

It should be noted that the animals treated with barium salts were watered at the creek and thus received a considerable amount of sulphates, which may have had some effect in neutralizing the barium. As has already been remarked, the amount of sulphates in the creek water would make an equivalent of about 40 grams daily of magnesium sulphate for the average quantity of water consumed by a 1,000-pound animal. These sulphates would theoretically neutralize an equivalent amount of a barium salt. The animals treated were brought into the corrals at night and the barium salt was given to them in the morning, or, in the case of larger doses, both at night and in the morning. After being dosed they were driven into the pasture, where they immediately went to feeding and did not ordinarily go to water for some time. This gave the barium a chance to produce an effect before coming in contact with the sulphates. The animals were not regular in their habits of drinking, however, and it is very possible that in some cases the lack of effect from small doses may have been due in part to the sulphates of the drinking water. The possibility should be recognized that the high lethal dose may be accounted for by the antidoting effect of the water used. It was not practicable, with the experimental material available, to feed barium to animals watered on sulphate-free water.

While there is this possibility of an effect of barium neutralization by the drinking water, it is the impression of the writer that in the experimental animals as a whole the toxicity of the barium salts was modified very little. This seems the more probable when it is remembered that the lethal dose for the rabbits at Hugo corresponded very well with the results recorded by others. The water used by the rabbits contained, per million, 169.17 parts SO_4, while the creek water used by the larger animals contained 637.4 parts SO_4.

CUMULATIVE EFFECT.

There is a certain amount of cumulative effect.

No. 10 succumbed after 7 doses of 45 grams each and one dose of 50 grams.

No. 114 received 25 grams daily for something over four days. It is impossible to tell just how much the steer took from September 9 to September 14.

No. 116 received 35 grams daily for eight days before succumbing.

No. 109 received 10 grams for three days.

In all these cases the barium was fed in gradually increasing amounts, and it had been found, as already stated, that the lethal dose was in the neighborhood of 1 gram to 8,232 grams of weight. This amount was given to No. 99 and it succumbed after the second dose.

While there is a cumulative effect in large doses, small doses seem to have no similar result. Possibly the poison is excreted with sufficient rapidity to prevent any toxic effect from small doses.

TOLERATION.

There is little evidence of toleration or acquired immunity to the effects of the poison. No. 10, which received doses of barium for nearly four months, succumbed to the same dose relatively to its weight as that which killed No. 99 in two doses. In all cases the length of time during which the doses were repeated seemed to have little effect in modifying the lethal dose.

SYMPTOMS.

Small doses had no effect upon the appetite and gave no loss of weight. During the period when the doses approached the toxic limit there seemed to be a small loss of weight in most cases. This loss of weight was especially pronounced in steer No. 10. With rabbits death was preceded by a period of weakness, when the hind legs seemed to be especially affected, accompanied by rapid respiration, rapid heartbeat, and convulsions. To most of the cattle death came very suddenly, with few pronounced symptoms. In steer No. 10 the symptoms were more noticeable than in any other case; its previous loco poisoning may have had something to do with this condition. Generally speaking, with the cattle small doses produced no symptoms, even when continued for a long time. When the dose which was to prove fatal was reached, symptoms of weakness and pain might be developed, but in most cases death seems to have come with no previous symptoms. Apparently the animal fell in its tracks and died without much movement.

POST-MORTEM APPEARANCES.

The post-mortem appearances agreed in general with those noticed by previous writers on the subject of barium poisoning. The heart was generally in systole, the left ventricle being almost always contracted and empty. The mesenteric blood vessels were injected and, generally, the central nervous system was congested. The inner walls of the stomach and small intestines were more or less inflamed. The inflammation in the stomach was more marked in the pyloric end, and in the intestines inflammation was more distinct in the duodenum and cæcum. The large intestines were not affected. The extent of the inflammation varied with the acuteness of the poisonous effect, but was always marked. No ulcers were noticed except in No. 10, and in this animal they may have been due to previous loco poisoning.

COMPARISON OF LOCO POISONING WITH BARIUM POISONING.

The symptoms of loco poisoning have been summarized by the writer in a previous publication and may be briefly stated as follows: The first pronounced symptom is in the gait, which is stiff, with more or less evidence of partial paralysis. There is a lack of muscular coordination, which produces "high stepping," rearing and jumping, and stumbling. In drinking, the mouth moves in a peculiar way, something like in eating, a movement which is more easily recognized than described. The animal is either dull and dejected or in constant motion, as the result of a disorganized nervous system. It gradually loses flesh, its coat becomes rough, its eyes staring, it becomes profoundly anæmic, and eventually it dies of starvation. Ulcers are found on the inner walls of the stomach of horses and of the fourth stomach of cattle and sheep. The brain and spinal cord are hyperæmic and a mass of serous exudate more or less coagulated is formed in the epidural space of the spinal canal. Abortion is common in locoed animals. It should be noticed, too, that these symptoms come on gradually as a result of prolonged feeding.

In the animals subjected to prolonged barium feeding no peculiarities in walking were noticed, such as the stiff gait and high stepping, nor any evidence of muscular incoordination. With the exception of steer No. 10, all the animals used their limbs in the normal manner. Weakness in the hind limbs of the rabbits at the time when the toxic dose was reached, as in steer No. 10, was not comparable with the paralytic effects in the locoed animals. There was no effect upon the muscles of the mouth. The animals showed no dullness and no unusual nervous symptoms. They gained in weight during the prolonged feeding of small doses or, as in the cases of the two horses which were in fine condition at the beginning of the experiment, held their own with no loss. There was no loss in weight until the dose was increased to the limit which produced acute symptoms. The barium-fed animals did not become anæmic. No ulcers were found in the stomach. No serous exudate collected in the spinal canal. The congested condition of the central nervous system, however, may be compared with the hyperæmia of the brain and cord in the locoes. Barium is said to produce abortion and while our experiments are not conclusive on this point we had one or two cases of abortion in rabbits which may have been caused by the barium. The noticeable thing in the comparison is that the general nervous symptoms and emaciation, which are usually considered characteristic of chronic loco poisoning and are very easily recognized by one familiar with cattle and horses in loco-infested regions, were entirely absent.

There was not the slightest evidence that the barium-fed animals became locoed. This becomes strikingly evident when barium-fed animals are compared with those to which loco was fed. One gram of the loco weeds which were fed in Hugo during the season of 1908, according to the analyses of the Bureau of Chemistry, contained on an average an equivalent of nearly 0.0002 gram of barium salts. Knowing the amount of loco fed daily, it is easy on the basis of these analyses to estimate approximately the amount of barium salts received by the animals to which loco was fed in the corrals. In the case of the corral-fed animals Table II shows the average daily feed of loco, the approximate amount of barium salts contained in this ration, and the length of time which elapsed before symptoms of loco poisoning developed.

Table II.—*Average daily ration of loco, the approximate amount of barium salts contained therein, and the length of time required to develop loco poisoning.*

Serial No. of animal.	Daily ration.	Barium salts.	Time required to develop poisoning.
	Pounds.	*Grams.*	*Days.*
Cattle:			
35	5	0.5	77
6	10	1.0	70
84	10	1.0	101
68	7	.7	75
Horses:			
55	8	.8	71
57	8	.8	33
70	8	.8	75

In like manner, for purposes of comparison, Table III shows the daily doses of barium salts fed to the animals and the length of time the experiment was continued during which no symptoms of loco poisoning developed.

Table III.—*Daily doses of barium salts fed to animals and length of time fed with no resulting symptoms of loco poisoning.*

Serial No. of animal.	Barium salts.	Length of time fed.
	Grams.	*Days.*
Cattle:		
92	1.13 to 15	119
46	1.5 to 60	119
10	1.5 to 50	104
113	10.0 to 25	68
114	5.0 to 25	59
115	5.0 to 26	68
116	10.0 to 35	58
Horses:		
61	10.0 to 35	72
62	1.15 to 30	123

In comparing Tables II and III it will be noticed that for all the animals which were fed weighed rations of loco in the corrals, the amount of barium salts received in the loco varied from 0.5 to 1 gram daily and that these animals showed distinct signs of loco poisoning at periods varying from 33 to 101 days. On the other hand, the animals receiving doses of barium received amounts varying from 1.13 to 60 grams daily. In all cases the small dose was continued for a considerable period of time, until it was evident that no symptoms would develop. These animals were fed for periods varying from 58 to 123 days. The periods during which barium salts were fed are therefore seen to be rather longer than those during which loco was fed to the animals in the corrals. The total amounts of barium received in the cases of the barium-fed animals were, in the long run, very much greater than in the cases of the loco-fed animals. If only large doses of barium had been fed, it might be said that the cases of poisoning were all cases of acute poisoning; but the smaller doses were continued for a long period of time, and large doses were administered only when it appeared certain that no symptoms of so-called loco poisoning would develop and when it seemed best to determine the toxic limit for a given animal. If barium alone would produce symptoms of so-called loco poisoning, some one of the long list of animals which were fed during the summer should have developed the characteristic symptoms of this disease. In the light of these facts the failure in the experiments of using sulphates as antidotes for loco poisoning would seem to be partially explained. If barium were the cause of the poisoning, it would seem probable that the administration of sulphates would at least produce some mitigating effect, even had it not served as a perfect antidote. The fact that the animals which received these sulphates were locoed fully as quickly as they would have been without the administration of the antidote would lead one to suspect that the true cause of the symptoms of loco poisoning was something other than barium. Reference may be made in this connection to C. D. Howard's paper on "Occurrence of Barium in the Ohio Valley Brines and Its Relation to Stock Raising."[1] There seems to be no doubt that he rightly ascribes the deaths of the animals to barium poisoning, and that it is probable that deaths of other animals have been caused in this region in the same way. Yet this is a part of the country where symptoms like those seen in locoed animals are unknown.

While these results seem to indicate clearly that barium will not produce the symptoms of so-called loco poisoning, it should be noted, perhaps, that it does not by any means follow that barium may not be a factor in the production of this disease. It would appear that there are in the loco plants certain properties or combinations of properties as yet undiscovered which will produce the series of symptoms known as loco poisoning.

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[1] Bulletin 103, West Virginia Agricultural Experiment Station, 1906.

SUMMARY.

(1) Granted that barium is the cause of loco poisoning, sulphates form a logical antidote.

(2) Experimental administration of magnesium sulphate and sulphuric acid in amounts much greater than those necessary to neutralize barium in the loco eaten had no antidotal effect.

(3) Experimental feeding of barium salts produced symptoms which corresponded in general to those recorded in literature in acute poisoning, but without marked cumulative effect or acquired toleration, while the lethal dose was higher than that noticed by most observers. The post-mortem appearances corresponded to those recorded in acute poisoning.

(4) The symptoms and pathology of barium poisoning differed in a marked degree from those noted in loco poisoning. Typical loco poisoning is not produced by barium feeding alone.

II.—LABORATORY STUDIES ON THE RELATION OF BARIUM TO THE LOCO-WEED DISEASE.

By C. L. Alsberg and O. F. Black, *Chemical Biologists, Drug-Plant, Poisonous-Plant, Physiological, and Fermentation Investigations.*

INTRODUCTION.

Dr. A. C. Crawford[1] has reported the presence of barium in loco plants from Colorado and has published a chemical and pharmacological study on which he bases the conclusion that barium is a cause of the loco-weed disease. A conclusion of so much practical interest and importance as this would seem to demand that further study be given to the action of barium in the loco-weed disease. It gives rise to a series of problems connected with the possibility that plants may, under certain conditions, derive harmful constituents from the soil. One of these problems is to determine whether barium is also taken up by other plants growing on the same barium-containing soils as the loco plants or whether the loco plants possess a specific selective preference for barium as a result of which they alone, of all the plants growing under the same condition in these regions, absorb enough to become toxic. Another problem is to investigate whether plants from other parts of the United States where barium occurs as a mineral also contain this metal and if so whether they also are toxic. The form in which barium occurs in these plants and in their ash is also a question of considerable interest. Still another problem has been investigated by the Bureau of Soils, the results of which show that barium is widely distributed in soils.[2] Some of these problems have been studied and the results are presented in this paper.

OCCURRENCE OF BARIUM IN VARIOUS PLANTS FROM COLORADO, WYOMING, AND ARIZONA.

The first step in this investigation was a search for barium in different species of plants from the regions where the loco-weed disease prevails.

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[1] Crawford, A. C. Barium, a Cause of the Loco-Weed Disease. Bulletin 129, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908.

[2] Failyer, G. H. Barium in Soils. Bulletin 72, Bureau of Soils, U. S. Dept. of Agriculture, 1910.

The determinations of barium were made in the manner described by Hillebrand.[1] In most cases, as a matter of precaution, the barium sulphate finally obtained was again fused and treated with oxalate in the usual way, in order to remove traces of any calcium that may have contaminated it. In many cases the precipitates were examined with the spectroscope for contamination. They never carried more than a trace of calcium. The results are given in Table IV.

TABLE IV.—*Barium content of various plants from Colorado, Wyoming, and Arizona.*

Analysis No.	Plant, collection number, and locality.	Moisture in air-dried plant.	In dried plant.			In ash.	
			Ash.	Barium sulphate.	Calcium oxid.	Barium sulphate.	Calcium oxid.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	Alfalfa (M. 90, Hugo, Colo.)	9.32	8.55 9.14	0.014		0.150	
2	Alfalfa (M. 9.65, Limon, Colo.)	6.34	6.47	.010		.159	
3	Alfalfa (M. 9.43, Hugo, Colo.)	6.96	7.21	.003	1.47	.041	19.52
4	*Astragalus nitidus* Dougl. (Woodland Park, Colo.)	8.53	9.94 10.03	.043 .042		.436 .423	
5	*A. mollissimus* Torr. (M. 9.95, Hugo, Colo.)	8.50	16.60 17.48	.032 .029		.198 .168	
6	*A. simplicifolius* Gray (M. 9.4, Buckman, Wyo.)	6.14	24.74 28.90	.022 .029		.088 .100	
7	*A. mollissimus* Torr. (M. 9.195, Hugo, Colo.)	5.58	6.09	.016		.273	
8	*A. thurberi* Gray (Tm. 3, Calabazos, Ariz.)	6.69	7.71 8.18	.009		.120	
9	*A. mollissimus* Torr. (M. 9.45, Hugo, Colo.)	7.32	7.47	.003	.85	.034	11.36
10	*Aragallus lamberti* (Pursh) Greene (M. 8.96, Hugo, Colo.)	5.79	17.82 17.81	.023 .023		.131 .160	
11	*A. lamberti* (Pursh) Greene (M. 9.68, Limon, Colo.)	5.91	23.01	.006		.027	
12	*Lupinus pusillus* Pursh (M. 9.27, Mount Carbon, Colo.)	7.84	16.31 16.26	.019 .021		.114 .130	
13	*L. sericeus* Pursh (M. 9.38, Hugo, Colo.)	7.56	10.60	.017	3.90	.168	36.87
14	*L. pusillus* Pursh (M. 9.71, Limon, Colo.)	7.20	6.85	.005		.069	
15	*L. parviflorus* Nutt. (M. 9.56, Mount Carbon, Colo.)	7.14	5.51	0	1.95	0	35.40
16	*Buchloe dactyloides* (Nutt.) Engelm., buffalo grass (M. 9.46, Hugo, Colo.)	9.37	14.45	.015		.104	
17	Barley (M. 9.49, Hugo, Colo.)	9.80	10.07	.008		.079	
18	Millet (M. 9.41, Hugo, Colo.)	9.80	14.53	.006		.043	
19	*Andropogon scoparius* Michx. (grass; M. 9.47, Hugo, Colo.)	5.74	1.11	0	.95	0	8.60
20	Beet (M. 9.204, Hugo, Colo.)	(1)	5	0			
21	*Yucca glauca* Nutt. (M. 9.208, Hugo, Colo.)	(1)	5.5	0			
22	*Calamovilfa longifolia* (Hook.) Hack. (M. 9.115, Hugo, Colo.)	(1)	4	0			
23	*Artemisia filifolia* Torr. (M. 9.119, Hugo, Colo.)	(1)	6.5	0			
24	*Ipomoea leptophylla* Torr. (M. 9.206, Hugo, Colo.)	(1)		(2)			

[1] Not determined.

[2] Five milligrams in 50 grams of the wet root.

Inspection of Table IV shows that many species besides loco plants contain barium in amounts not differing greatly from those found in the two loco genera, Aragallus or Oxytropis and Astragalus. Thus alfalfa (Nos. 1, 2, and 3), *Lupinus pusillus* (Nos. 12 and 14), *Lupinus*

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[1] Hillebrand, W. F. Analysis of Silicate and Carbonate Rocks. Bulletin 305, U. S. Geological Survey, 1907, p. 116.

sericeus (No. 13), buffalo grass (No. 16), barley (No. 17), and millet (No. 18) contain barium in larger or small proportions. *Lupinus parviflorus* (No. 15), the grasses Andropogon (No. 19) and Calamovilfa (No. 22), the beet (No. 20), the yucca (No. 21), and the Artemisia (No. 23) contain none. Crawford also found barium in different botanical families.[1] While it is true that the average barium content of the loco plants is greater than that of the other plants, in many cases this difference is not great. Assuming that the barium is equally toxic wherever found, we would expect such plants as alfalfa (No. 1) and *Lupinus pusillus* (No. 12) to be more toxic under range conditions than such loco weeds as *Astragalus thurberi* (No. 8) and *Astragalus mollissimus* (No. 9), both of which contain far less barium. For this there is, of course, no evidence. In the laboratory, under certain quite arbitrary methods of preparing and feeding the extracts, both the alfalfa (No. 1) and the *Astragalus mollissimus* (No. 9) proved toxic, as may be seen by reference to protocols Nos. 5, 6, and 11[2] discussed in detail further on in this bulletin. These show that under artificial laboratory conditions no parallelism between barium content and toxicity was found. Hence, no evidence was discovered to corroborate older observations claiming that barium-free loco plants are not toxic.[3] Indeed, the loco poorest in barium was quite as toxic in the laboratory as the richest, as shown in the protocols.

OCCURRENCE OF BARIUM IN PLANTS FROM VIRGINIA.

As barium seemed to be present so frequently in plants occupying the same areas in Colorado as the loco plants, it seemed important to determine whether plants growing in other sections of the United States where barium occurs as a mineral also contain it. Pittsylvania, Campbell, Bedford, Tazewell, Russell, and Fauquier Counties in Virginia contain deposits of baryta, some of which have been developed commercially.[4] Plants were therefore collected at Evington in Campbell County, at Toshes and Pittsville in Pittsylvania County, at Gardners in Russell County, and at Catlett in Fauquier County. The barium determinations from plants thus collected gave the results shown in Table V.

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[1] Crawford, A. C. Op. cit., p. 54.

[2] The protocols are collected at the end of this paper, pp. 56 to 61.

[3] Crawford, A. C. Op. cit., pp. 66–71.

[4] Watson, T. L. Geology of the Virginia Barite Deposits. Transactions of the American Institute of Mining Engineers, vol. 38, p. 710.

TABLE V.—*Barium content of Virginia plants from regions where barium occurs as a mineral.*

Analysis No.	Plant, collection number, and locality.	Moisture in air-dried plant.	In dried plant.		Barium sulphate in ash.
			Ash.	Barium sulphate.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
25	*Andropogon virginicus* L. (broom sedge; A. 59, Gardners, Va.)	6.01	3.30	0.029	0.876
26	Grass (mainly crab-grass; A. 35, Pittsville, Va.)	6.16	8.45	.029	.343
27	Soy bean (A. 36, Pittsville, Va.)	8.10	6.17	.023	.36
28	Hay (A. 19, Evington, Va.)	5.50	5.53	.014	.26
29	*Panicum sanguinale* L. (crab-grass; A. 49)	5.54	6.60	.010	.147
30	*Andropogon virginicus* L. (broom sedge; F. 19, Evington, Va.)	5.72	5.74	.007	.158
31	Wheat (seed; A. 34, Pittsville, Va.)	(1)	±2.00	0	0
32	Maize (ear, leaf, and stem; A. 50, Toshes, Va.)	(1)	±1.5	0	0
33	Maize (ear, leaf, and stem; A. 61, Gardners, Va.)	(1)	±2.0	0	0

[1] Not determined.

Inspection of Table V shows that many of these plants contain barium. The soy bean plants from Pittsville and the hay from Evington contain as much barium as the loco plants from Colorado shown in Table IV. The soy beans grew in a field with cowpeas. The hay from this field was used year after year as fodder without the least ill effects. The field was several hundred yards from an old baryta working with a very small dump, but contamination from this source was impossible. The hay came from a field in the bottom just southwest of the railroad station at Evington, 2 miles from the nearest mine. It was taken from a barn where it had been stored for stock feed. Although the soils on which these plants grew contained barium, no condition resembling the loco-weed disease is known to have affected live stock in Virginia.

On the whole, a study of Tables IV and V does not show any very great selective absorption of barium by the loco plants. Obviously it is quite impossible to prove selective absorption by loco plants without a study of plants growing on the same plat. Variations in the soil, even within a limited area, might well be sufficient to account for the results. It was possible in several instances to examine plants growing adjacent to one another. Buffalo grass (No. 16), barley (No. 17), millet (No. 18), alfalfa (No. 3), and *Astragalus mollissimus* (No. 9) were all collected upon the same kind of soil less than one-quarter of a mile from one another. All of them contained barium. It is curious to note that the alfalfa (No. 3) and the Astragalus (No. 9) contain the least, while the buffalo grass (No. 16), one of the best forage grasses of the Plains, contains the most. The best (No. 20), the morning-glory root (No. 24), the yucca (No. 21), and *Astragalus mollissimus* (No. 7) were also collected very close to one another. Their barium content varies. Artemisia (No. 23) and the grass Calamovilfa (No. 22), neither of which contains barium, also grew close together. The roots were removed from the buffalo grass (No. 16) before analysis because they contained soil. Of the beet (No. 20) and morning-glory (No. 24), only the roots were analyzed. In all other cases the entire plants were taken for analysis. The barley and the millet, although in seed, had not ripened.

It is possible that the barium found in these plants is not really present within them, but is derived from the earth and dust which cling to their exterior. As the writers were compelled to use plants gathered by others, who employed no special precautions in collecting them, it was necessary to take particular pains in the preparation of material for analysis. It is possible, too, that the differences in the barium content are due to the different degrees in which dust clings to different plants. While some of the plants studied were very hairy and would therefore retain much dust, others were quite smooth and would retain much less. To avoid these sources of error as far as possible, the plants were carefully cleaned and brushed before they were ground for analysis. It is not certain that this procedure removed all the earth, but such seemed to be the case. Moreover, only such plants were selected as seemed clean and free from soil. It was not practicable to wash the plants, for this leaches out salts and does not clean them well. The carefully cleaned plants were ground in a drug mill and thoroughly sampled. A considerable number of individual plants were always ground up together in order to obtain as fair a sample as possible. While these precautions may not have eliminated the sources of error, it does not seem likely that the latter entered materially into the results. The fact that in some instances the soil, as shown by the analyses of Prof. G. H. Failyer, of the Bureau of Soils, contained less barium than the ash of plants growing upon that soil is presumptive evidence that this metal was actually contained in the plant. Furthermore, the fact that the separate analyses of the leaves, the stems, and the roots of *Aragallus lamberti* (Nos. 34, 35, and 36) show the greatest amount of both ash and barium in the leaves (Table III) indicates the same fact, for if the presence of barium were due to contamination with soil the greatest amount ought to be in the root and the least in the leaf. The barium, however, accompanies the other salts, and it is well known that as a rule the actively growing leaves of plants contain greater amounts of ash than the roots and stems. Aragallus is no exception. These determinations of barium in the leaves also furnish, possibly, an explanation for the occasional variations in ash and barium content of the same species growing in the same locality. The results obtained for different specimens would be comparable only if the entire plants were always analyzed at the same stage of growth. The samples analyzed were not necessarily uniform in this respect. Against the evidence in

Table VI must be balanced the observation that the beet (No. 20), which was free from barium, was carefully peeled, and only the interior, which had never been in contact with the soil, was taken for analysis. The morning-glory root (No. 24), however, could not with absolute certainty be freed from soil.

TABLE VI.—*The distribution of barium in Aragallus lamberti (Pursh) Greene.*

Analysis No.	Plant, collection number, and locality.	Moisture in air-dried plant.	In dried plant.		Barium sulphate in ash.
			Ash.	Barium sulphate.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
34	*Aragallus lamberti* (leaves; M. 8.96, Hugo, Colo.)	6.69	22.02	0.034	0.156
35	*A. lamberti* (stems; M. 8.96, Hugo, Colo.)	7.12	9.10	.027	.298
36	*A. lamberti* (roots)	6.00	7.92	.020	.258

With the plants from Virginia further precautions were possible. In gathering them each plant or tuft of grass was carefully cut off well above the soil. The soy beans were further sorted in the laboratory and only the clean tops used. The pods had formed, but the seeds were not quite ripe. As the plants were erect and about 18 inches tall, the chance that soil contaminated the tops is small. The hay from Evington was taken from a barn.

At any rate, whatever the source of the barium, it reaches the intestines of the stock browsing upon such forage plants as contain it, so that the possibility of its affecting them must be considered.

SOLUBILITY OF BARIUM IN LOCO PLANTS.

Some of the salts of barium, particularly the sulphate and silicate, are very insoluble. The sulphate is so insoluble that it is believed to be quite harmless, though the soluble salts of barium are quite toxic. Indeed, baryta, because it is supposed to be harmless and is very white and very heavy, is said to be used as an adulterant in many articles of commerce, sometimes even in articles of diet. Hence, it is important to know whether the barium present in these plants is soluble. We have not found it appreciably soluble in water in any dried loco plants examined, which corroborates some of the observations of Crawford.[1] Following his procedure, extracts were prepared by means of peptic and tryptic digestion.[2] The finely ground plant was percolated with about 10 liters of water, saturated with chloroform to prevent putrefaction. The residue was then digested at 38° C. for 12 to 24 hours with a solution of pepsin in 0.15 per cent hydrochloric acid to which much toluol and chloroform had been added. The liquid was filtered off and added to the percolate; the residue was digested a second time with a solution of trypsin in 0.2 per cent sodium carbonate containing much chloroform and toluol. The liquid was filtered from the residue and also added to the percolate. The combined extracts were then neutralized and concentrated under diminished pressure, a difficult and painstaking task because of the foaming. The residues were dried and preserved for analysis. Barium was determined separately in the dry residues and the concentrated extracts. The results are given in Table VII.

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[1] Crawford, A. C. Op. cit., p. 68.
[2] Crawford, A. C. Op. cit., pp. 66–71.

TABLE VII.—*Determination of barium in the extract obtained by digestion of loco weeds and other plants and in the residue from such digestions.*

Analysis No.	Plant, collection number, and locality.	Barium sulphate in 100 grams—		Barium sulphate in the extract of 100 grams dry plant.
		Of the dry plant.	Of the dried residue after digesting and extracting the plant.	
37	Alfalfa (M. 9.65, Limon, Colo.)	0.010	(1)	0.0074
38	*Astragalus thurberi* Gray (Tm. 3, Calabazos, Ariz.)	.009	0.010	.0001
39	*Astragalus mollissimus* Torr. (M. 9.195, Hugo, Colo.)	.016	(1)	.0006
40	*Aragallus lamberti* (Pursh) Greene (M. 8.96, Hugo, Colo.)	.023 .028	.043 .051	.0016
41	*Astragalus nitidus* Dougl. (Woodland Park, Colo.)	.043 .042	.052	.004
42	Alfalfa (M. 90, Hugo, Colo.)	.014	.014	(1)
43	Soy bean (A, Pittsville, Va.)	.023	.033	(1)
44	*Astragalus simplicifolius* Gray (M. 9.4, Buckman, Wyo.)	.022 .029	.029	(1)
45	*Astragalus mollissimus* Torr. (M. 9.95, Hugo, Colo.)	.032 .029	.029	(1)

[1] Not determined.

Inspection of Table VII shows that the barium content of the insoluble part of the plants was either relatively unchanged or relatively markedly increased. The increase is due to the fact that the extraction had removed much soluble material, concentrating the barium in the insoluble residue. There is one record in the literature of a barium determination in a residue left after an extraction by digestion of this type,[1] and in it no barium was found. When one considers that at times in the exact determination of such small quantities of barium the precipitate may be unusually slow in forming, it is evident that no great weight need necessarily be placed upon a single experiment. The writers, particularly in the beginning of their work, had an occasional misleading determination, as duplicate analyses showed. As is evident from an inspection of Table VII, these results were controlled in five instances by analyzing the extracts obtained by digestion. The extracts were evaporated to a sirup, transferred to platinum, and ashed. Barium was determined in the ash in the manner recommended by Hillebrand.[1] The amount of barium was very small, hardly more than a trace. In the extract from 100 grams of the dry plant it varied from a maximum of 0.0074 gram barium sulphate in the alfalfa to a minimum of 0.0001 gram barium sulphate in the *Astragalus thurberi.* The source of these traces of barium is not quite clear, for the only three extracts tested for soluble sulphates, *Astragalus thurberi* (No. 38), *Astragalus mollissimus* (No. 45), and alfalfa (No. 37), contained appreciable amounts, certainly more than enough to convert all the barium into sulphate. Moreover, it was not easy to filter the extracts absolutely clear, and it was difficult, owing to their dark color, to know when they were clear. The extract of *Aragallus lamberti* (No. 40) was filtered through ordinary folded filters. It is not certain, therefore, that traces of precipitated barium sulphate did not pass through the filter. *Astragalus thurberi* (No. 38), *Astragalus mollissimus* (No. 39), and alfalfa (No. 37) were filtered through Schleicher and Schüll quantitative filters No. 590. While it is possible, although unlikely, that the traces of barium found in the extracts may have been due to imperfect filtration, there is another and more probable explanation dependent upon the normal solubility of barium sulphate. This salt is soluble in distilled water to the extent of about 2.5 milligrams to the liter.[2] As a number of liters were used for each extraction, the surprising thing is not that traces of barium were found, but that there was so little. Probably the explanation is that either the small amount of barium present in the air-dried plant occurs in combination with silica which is abundantly present or that other substances in the solution affect the solubility. Perhaps there are traces of organic compounds of barium. In this connection it is interesting to note that the alfalfa, which was relatively poor in ash and silica and rich in calcium, yielded more barium to the extract relatively and absolutely than the loco plants. These determinations of the barium content of extracts of air-dried plants are, as far as known to the writers, the only ones recorded in the literature of the subject.[3] Indeed, they are not aware that anyone before them has ever tested toxic loco extracts for barium.[3] It has, to be sure, been suggested that plants might be found in which the barium is not extracted by digestion.[4] The writers have found such plants and no others. Fresh plants they have not examined.

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[1] Crawford, A. C. Op. cit., p. 67.

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[1] Hillebrand, W. F. Loc. cit.

[2] Fresenius, C. R. Quantitative Chemical Analysis, vol. 1, New York, 1908, p. 169.

[3] Crawford, A. C. Op. cit., pp. 67–68.

[4] Crawford, A. C. Op. cit., p. 70.

RELATION OF BARIUM TO TOXICITY.

All these observations argue against the specific toxic action of barium in loco plants. The amounts of barium present in the extracts were too small to prove fatal; in fact, they were hardly more than traces. It has, moreover, been shown that this metal is present in some insoluble form, probably as sulphate or silicate. From the extract of 200 grams of *Aragallus lamberti* (No. 40) only 0.0032 gram barium sulphate, corresponding to 0.0023 gram barium chlorid, was obtained. Now Crawford has shown that the extract obtained from 200 grams of air-dried *Astragalus mollissimus* by digestion is the toxic dose for a rabbit of about 1 kilogram,[1] an observation which the writers can completely corroborate. The toxic dose of barium chlorid when given in one or two feedings lies between 0.1 and 0.2 gram.[2] The toxic dose of extracts fed in this investigation contained from one-fiftieth to less than one-hundredth as much barium as this. The death of rabbits in 5 to 16 days from the feeding of smaller amounts of barium chlorid (0.025 gram daily) has been reported.[2] The extracts prepared by the writers contained from one-fiftieth to less than one-tenth of these small, slowly killing doses. Nevertheless, these extracts were very toxic, proving fatal within 24 hours. Rabbits were killed by feeding extracts of from 200 to 250 grams of air-dried *Astragalus arizonicus*, *Astragalus thurberi*, *Aragallus lamberti*, *Astragalus mollissimus*, and *Astragalus nitidus* in a single dose or in two divided doses separated by an interval of 24 hours, as may be seen by reference to protocols Nos. 1, 2, 7, 11, and 19. Furthermore, similar extracts of alfalfa were often fatal in a like way. Of four experiments with alfalfa, as shown in protocols Nos. 3, 5, 6, and 8, fatal results were recorded three times.

It will be seen from Table VII that the soy bean from Virginia behaved in a similar way as regards solubility of its barium. It did not yield more than traces of barium on extraction. It differed, however, in not yielding a toxic extract, as shown by protocol No. 20. The dosage fed was somewhat less than in the experiments with the loco plant. Moreover, as but one animal experiment was performed, the lack of toxicity of Virginia plants under these artificial laboratory conditions is not proved absolutely. Barium in dried Virginia and Colorado plants is present in an insoluble form. If, nevertheless, it is a cause of loco poisoning the same trouble is to be expected with Virginia cattle. No evidence of such trouble could be discovered. This is the more significant as Russell and Tazewell Counties, Va., are very successful grazing and cattle-growing districts. Of course this is not conclusive. It is still possible that the barium is present in different combinations in the different plants. Such a difference, if present, could hardly be the result of a difference in the barium compounds of the soil, for both in Virginia and Colorado the barium occurs in a form in which it is but very slightly soluble in dilute acid.[1] Moreover, Marsh reports that the waters in the region from which the tested plants came contain much sulphate, which would certainly convert the barium into the sulphate.

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[1] Crawford, A. C. Op. cit., p. 46.
[2] Crawford, A. C. Op. cit., pp. 57 ff.

The possibility that the barium is harmless in all the plants in which it occurs except the loco plants, because it is physiologically antagonized by other salts or substances in all of them except in the loco plants, is conceivable though not probable. To test this possibility would involve a long research, which does not seem worth the labor in view of the fact that the toxic extracts obtained in the laboratory contain but traces of barium and in view of the equally significant fact that some alfalfa extracts are under the same conditions quite as toxic.

TOXICITY OF ASH EXTRACTS.

As the extracts contained only traces of barium and as so harmless a plant as alfalfa was, under the extreme conditions of the laboratory experiments, often quite as toxic as loco plants, it seemed necessary to analyze the toxic action further. This was rendered easier by Crawford's discovery that the acetic-acid extracts of the ash of loco plants, freed from the excess of acid, were fatal when fed to rabbits.[2] This experiment was repeated with the specimen of alfalfa which contained almost no barium. As will be seen by reference to protocol No. 8, the extract prepared from this plant by digestion was very toxic. In a sample of the ash of 600 grams of this plant, barium sulphate and calcium oxid were determined, showing 0.003 per cent barium sulphate and 1.47 per cent calcium oxid in the dry plant. The remainder of the ash was extracted with an excess of acetic acid. The extract was made up to a known volume and a portion equivalent to 200 grams of dry alfalfa taken. This was dried down on the water bath to remove the acetic acid, and the residue was baked for half an hour at 150° C. in the oven to remove any acid remaining. After cooling, the residue was suspended in water. It was not completely soluble, probably because of the coagulation of silicates; perhaps, also, because of the formation of basic salts. The reaction was slightly alkaline. This milky-white liquid, containing some insoluble matter in suspension, was fed to a rabbit in two doses, one in the forenoon and one in the afternoon, with fatal results, as shown in protocol No. 8. The liquid, a portion of which was fed in this experiment, contained no barium. The amount fed contained 11.2 grams calcium acetate. Consequently, in the experiment 11 grams of calcium were fed in addition to any other soluble salts that may have been present in the ash. Now, 5 grams of calcium acetate have been reported sufficient to kill a rabbit weighing 652 grams.[1] This the writers have been able to confirm. Rabbits have been killed with corresponding doses of calcium chlorid as recorded in protocols Nos. 16, 17, and 18. Calcium chlorid was used instead of the acetate because, being an inorganic compound, it can be easily dried, so that the dosage is easier than with the acetate. The few experiments performed render it probable that the fatal dose for rabbits lies between 4 and 5 grams calcium chlorid per kilogram of body weight when this amount is administered dissolved in about 60 to 100 cubic centimeters of water in two equal doses separated by an interval of three or four hours. Five grams calcium chlorid contain as much calcium as do 7.118 grams calcium acetate.

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[1] Privately communicated by Prof. Failyer.

[2] Crawford, A. C. Op. cit., p. 47 ff.

Evidently there is in these alfalfas, under the laboratory conditions in which the ash of loco plants has been reported toxic,[2] enough calcium to kill animals without considering the toxic action of other salts contained in the plants, such as potassium. However, experiments with the acetic-acid extracts of ashed loco plants did not yield the same results. Though the extracts were made in the same way as that of the experiment with alfalfa given in protocol No. 8, they did not prove fatal, as appears in protocols Nos. 9, 10, and 13. Like the extract of the alfalfa ash, they contained no barium. No record that such extracts have ever been tested for barium could be found. Their ash seemed to contain less calcium and less soluble matter generally than the alfalfa ash. In protocol No. 10 the total amount of calcium acetate obtained in the extract of the ash of 300 grams of air-dried plant was 8.5 grams, equivalent to 3.9+ grams per kilogram of body weight. The calcium acetate of the experiment with alfalfa ash amounted to a dosage of 4.9 grams per kilogram of body weight. The calcium fed in the loco-ash experiment No. 10 was well below the lethal dose, while that found in the alfalfa-ash experiment approached the lethal limits. The loco plants ashed were such as yielded toxic extracts by the digestion method. That in these experiments, unlike those previously reported,[3] the ash of these loco plants failed to yield fatal extracts may be due partly to the fact that larger rabbits were used and partly to the fact that the extract was fed in two doses separated by an interval of a few hours. In the fatal cases reported[3] the whole extract seems usually to have been fed in a single dose. This was heroic treatment to which it did not seem wise to resort, particularly as the loco plants are supposed to have cumulative action. The experience of the writers has been that an amount of calcium which may be fatal when administered in a single dose need not necessarily prove so when administered in divided doses at short intervals. This is quite in accord with the reports of experiments with the ash extracts.[1] In one case,[2] in which the extract was fed in two doses on two successive days, the rabbit died on the fourteenth day. In another case, in which a large rabbit was used, the extract from the ash of 200 grams of the plant did not prove fatal.[2] The facts that the writers failed to get fatal results with the ash extract of loco plants, that they did get fatal results with alfalfa-ash extract containing more salts than the loco-ash extracts, that none of the ash extracts contained barium, and that there is no record in the literature that they ever do contain barium furnish presumptive evidence that such fatal results as may be obtained in experiments of this kind are due rather to calcium and perhaps to other salts than to barium.

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[1] Crawford, A. C. Op. cit., p. 52.
[2] Crawford, A. C. Op. cit., p. 47 ff.
[3] Crawford, A. C. Op. cit., p. 48 ff.

If this line of reasoning is correct, then the reason why in the past nontoxic extracts were obtained from the ash when the extract was made with dilute sulphuric acid instead of acetic acid becomes clear.[3] By the former procedure the calcium was converted into the insoluble sulphate, in which form only a small fraction of it would pass into the extract. When the extract was then treated with lead carbonate to remove the excess of sulphuric acid, any calcium sulphate present in the solution would react thus:

$$PbCO_3+CaSO_4=PbSO_4+CaCO_3.$$

As calcium carbonate is very insoluble, practically all the calcium would be removed from the solution. These experiments indicate that the removal of the calcium must have made the solution harmless, for in this investigation barium was never found in the acetic-acid extracts of the ash.

It has been stated[4] that the extract of loco-weed ash made with 94 and 70 per cent alcohol proved toxic to rabbits in two cases. While this experiment was not repeated in this investigation, it is worth while in this connection to call attention to the fact that many potassium salts and also calcium oxid are fairly soluble in watery alcohol.

TOXICITY OF ALFALFA EXTRACTS.

The toxicity of the extracts of dry alfalfa is probably not dependent to so great an extent upon the calcium as is the case with the ash extracts, for the extract from the dry alfalfa plant does not contain as much calcium as the acetic-acid extract made from the ash. This was the case with the alfalfa used in protocol No. 8, described on page 58. As there shown, the acetic-acid extract of the ash contained 11.2 grams of calcium acetate. The same plant yielded but 3 grams of calcium calculated as acetate in the extract prepared by digestion.

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[1] Crawford, A. C. Op. cit., p. 48 ff.
[2] Crawford, A. C. Op. cit., p. 49.
[3] Crawford, A. C. Op. cit., pp. 52–53.
[4] Crawford, A. C. Op. cit., pp. 48–49.

The calcium in the extract was determined by incinerating the extract, digesting the ash with hydrochloric acid, and filtering. To the filtrate sulphuric acid and alcohol were added, and the calcium-sulphate precipitate was washed with dilute alcohol. The washed calcium sulphate was fused with sodium carbonate and the melt was dissolved in water and filtered. The residue of calcium carbonate was dissolved in dilute hydrochloric acid and precipitated with ammonium oxalate and ammonia. The precipitate was filtered off, washed, and ignited to constant weight over the blast lamp.

The alfalfa extract, which contained but 3 grams of calcium calculated as acetate, did not prove poisonous to a rabbit weighing 1,950 grams, as evidenced by protocol No. 3. Evidently the calcium in alfalfa behaves in a way similar to that of the barium in the loco plants; only a portion is extracted by digestion, at least in the one case examined. The alfalfa extracts which proved toxic in protocols Nos. 5 and 6 were given in somewhat larger dosage. Unfortunately their calcium content was not determined. It would seem that in these cases there was probably a summation of toxic actions; the action of calcium, potassium, and other salts, and perhaps the action of constituents as yet unstudied. The improbability of a physiological antagonism between salts playing a rôle has been pointed out. The alfalfa extracts differed from the loco-weed extracts in containing very much greater amounts of organic acids. When fed to rabbits they produced prompt diuresis and sometimes the passage of a moderate quantity of feces, effects not often noticed with loco-weed extracts. Perhaps these effects were due to the organic acids present.

It is interesting to note in this connection that the nontoxic extract of the Virginia soy bean already referred to differed markedly from the extracts of western plants in the very much smaller amounts of material extracted.

TOXICITY OF LOCO-WEED EXTRACTS.

The toxicity of the loco-weed extracts is perhaps dependent upon different causes, for the calcium in the one case studied seems to be more readily extracted than in the one sample of alfalfa studied. A weight of 100 grams of *Astragalus mollissimus* (analysis No. 9) yielded an extract containing 0.8514 gram calcium oxid, while the ash from the same quantity of plant yielded when extracted with acetic acid only 0.7864 gram calcium oxid. It is not justifiable to generalize from these two experiments, but so far as the evidence goes they seem to show that whereas in alfalfa only a portion of the calcium may be removed by extraction, in the loco weeds relatively more may be removed in this way. After ashing, the reverse seems to be the case.

If it is justifiable to conclude that calcium and probably other salts play an important part in the toxicity of these extracts prepared by digestion, this may be a clue to the reason why more toxic extracts are obtained by digesting with artificial gastric and pancreatic juices.[1] The hydrochloric acid of the gastric juice would render soluble the calcium present in the form of phosphate, carbonate, oxalate, and perhaps other insoluble compounds. If any of the calcium be present in the form of the insoluble salts of organic acids, the latter might also pass into solution. Now some organic acids, such as oxalic, are themselves quite toxic and, if extracted, would add their action to that of the other toxic constituents of the extract. To test the influence of the method of digestion upon the calcium content of the extract the writers determined separately (1) the calcium in the water extract, (2) the calcium in the extract obtained by digesting with artificial gastric juice the residue from the water extraction, and, finally, (3) the calcium in the extract obtained by the tryptic digestion of the residue from the gastric digestion. The results were as follows:

Calcium oxid.

	Gram.
(1) Water extract of 100 grams *Astragalus mollissimus* (M. 9.45)	0.7105
(2) Peptic extract of the residue from (1) (19.5 per cent of total calcium oxid extracted)	.1383
(3) Tryptic extract of the residue from (2)	.0026

As will be seen, more than one-sixth of all the calcium extracted was removed by peptic digestion. This is a quantity large enough to account for the greater toxicity of the extracts obtained by digestion.

COLLOIDAL BARIUM SULPHATE.

While the fact that by no method of digestion with an aqueous menstruum could extracts containing more than traces of barium be obtained renders it exceedingly improbable that the toxic action depended in any way upon barium, still it is conceivable that the traces of barium sometimes found in the extracts may have been present in some colloidal form far more active than any known compound of barium. Improbable though this assumption be, it was tested by preparing colloidal solutions of barium sulphate according to the method given by Feilmann.[1] A rabbit was fed 30 cubic centimeters of colloidal barium-sulphate solution the first day and 50 cubic centimeters on each of the two succeeding days, 6.5 grams colloidal barium sulphate in all, without any visible effects (protocol No. 21). While a single experiment of this sort is never finally conclusive, in view of the negative results obtained it did not seem worth while carrying this line of investigation further. The possibility of minute traces of barium acting in some occult way becomes still more improbable if one considers that the toxic effects of the ash extracts are amply accounted for by the other salts present. Moreover, the ash extracts did not contain even traces of barium. In the extracts of the unashed plants the cause of the toxic action is not so clear. These extracts were very concentrated and we may have had to deal with the action of other substances besides the salts. It is possible that they contain, in addition to the salts, some other toxic factor or factors. Crawford also considers it possible that the toxic action is the resultant of the action of the total constituents of the plant.[2]

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[1] Crawford, A. C. Op. cit., pp. 66–67.

All this work and the greater part of the work of Crawford was done with dry plants. While it has been shown that the dried plants used in this investigation do not contain appreciable amounts of barium in a soluble form, it is quite possible that it is otherwise with fresh plants. On this point the writers have no evidence. It is, however, exceedingly improbable, for Marsh[3] was able to produce the loco-weed disease in cattle with the dried plant in the same dosage, making due allowance for water lost in drying, and in the same length of time as with the fresh plant.

RESULTS OF PLANT ANALYSES AND TOXICITY EXPERIMENTS.

All this evidence, viz, the insolubility of the barium in dried loco plants, its presence in other species of Colorado plants, its presence in plants from Virginia, where the loco-weed disease is unknown, and the presence of large quantities of other salts in the extract, merely shows the inadequacy of the laboratory evidence connecting barium with the toxic action of the dry plants. These arguments can not be applied to the conditions of the range without further experimentation. Certainly the calcium and other salts which are so important a factor in the inspissated extracts prepared in the laboratory have nothing to do with the toxicity of these plants under range conditions. Moreover, while peptic and tryptic digestion in vitro does not lead to extracts containing more than traces of barium, conditions in the alimentary tract of cattle may be quite different. There unknown factors may conceivably come into play which perhaps cause barium to be absorbed. However much one may be inclined to doubt this possibility, without adequate experimental evidence, it is not right really to deny it. Before attacking this question it would be important to investigate whether the barium, which, as has been shown, is probably present in the plant in an insoluble form, is absorbed and enters into the metabolism of cattle.

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[1] Feilmann, E. Colloidal Barium Sulphate. Chemical News, vol. 98, 1908, p. 310.
[2] Crawford, A. C. Op. cit., p. 70.
[3] Marsh, C. D. Privately communicated.

ANALYSES OF THE BONES OF LOCOED ANIMALS.

Two ways of testing the problem whether the barium is absorbed presented themselves. One was to search for barium in the urine of animals upon a loco-weed diet. This was not a very promising line of attack, because the greater part of any barium that may be absorbed is excreted with the great bulk of the calcium in the feces, where it could not be distinguished from the unabsorbed barium.[1] The other line of attack was to analyze the carcasses of animals dead from the loco-weed disease. This the writers have not been in a position to do as completely as would be desirable. Mendel and Thacher[2] have, however, shown that the bones are storehouses of the earthy metals, especially strontium. Analagous observations have been made by König[3] and Lehnerdt.[4] The bones from two of the animals experimented upon by Marsh were accordingly secured and analyzed for barium, with absolutely negative results. Unfortunately, the animals had been dead for a year and their bones had been bleaching for that length of time upon the prairie. It may be that the barium had been removed by exposure to the weather, but in the presence of so much calcium this is not likely.

No. 10 was a steer, weighing 820 to 900 pounds, which had eaten some loco but had never been distinctly locoed. It had then received 1,437 grams of barium chlorid, 1/313 of its body weight, in divided doses from May 30 to September 10, when it succumbed.[6] Animal No. 55 was a horse that died of loco poisoning.[5] Barium was searched for as follows: The ash from 10 grams of the bones was fused with sodium carbonate, the melt dissolved in water, the insoluble residue filtered off and dissolved in weak hydrochloric acid, and the clear solution treated with a saturated aqueous solution of calcium sulphate. Not even a trace of barium could be detected. It is possible, of course, that this method was not suited to the end in view, but in control experiments in which traces of barium salts were added the latter were readily detected by this method.

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[1] Meyer, G. M. The Elimination of Barium. American Journal of Physiology, vol. 25, 1909, p. 142.

[2] Mendel, L. B., and Thacher, H. C. The Excretion of Strontium. American Journal of Physiology, vol. 11, 1904, p. 15.

[3] König, J. Substitution des Kalkes in den Knochen. Zeitschrift für Biologie, vol. 10, 1874, p. 69.

[4] Lehnerdt. Ueber den Einfluss des Strontium auf die intrauterine Entwicklung des Knochensystems. Münchener Medizinische Wochenschrift, vol. 56, 1909, p. 679. (Bericht des Vereins der Aerzte in Halle, a. S.) Lehnerdt. Strontiumfütterung an säugende Tiere. Münchener Medizinische Wochenschrift, vol. 56, 1909, p. 1976. (Bericht des Vereins der Aerzte in Halle, a. S.)

[5] The full history of this animal may be found in "The Loco-Weed Disease of the Plains," by C. D. Marsh. Bulletin 112, Bureau of Animal Industry, U. S. Dept. of Agriculture, 1909, and Part I of this bulletin, pp. 19–21.

[6] Marsh, C. D. Part I of this bulletin, p. 14.

DISCUSSION OF BONE ANALYSES.

If it be assumed that the failure to find barium in the bones of the locoed animal as well as in the bones of the animal fed soluble barium salts for months is reliable, it does not argue that barium can produce a chronic intoxication. Were the action of barium cumulative, it is likely that some trace of barium would remain in the bones. This is in accord with Marsh's[1] experiments, in which he was unabde to produce chronic intoxication by feeding barium over long periods. As far as our incomplete evidence goes, it does not argue for a long-continued storage of barium in the organism.[2] However, even if barium had been found in the bones, this fact would not prove that there was any connection between its occurrence there and loco poisoning. Thus, if the methods used be sufficiently delicate, arsenic may be found in many living things which never show symptoms of arsenical poisoning.

SUMMARY AND CONCLUSIONS.

The etiological factor in the loco weeds which is responsible for the toxicity of these plants in laboratory experiments is not barium.

This conclusion is based upon the following evidence:

Many kinds of plants from the Western States contain barium in amounts that are of the same order of magnitude as in loco plants. There is no evidence that such plants injure stock upon the range.

Many plants in certain sections of Virginia contain barium in quantities that are of the same order of magnitude as in loco plants. There is no evidence that such plants injure stock.

In dried loco plants barium is contained in an almost insoluble form. Even extracts prepared by digesting successively with artificial gastric and pancreatic juice contain but slight traces. Nevertheless, in large doses these extracts may be toxic.

There are usually enough salts of calcium, potassium, and metals other than barium in the extract of 250 grams of dried loco plant, the usual toxic dose for rabbits, to account for death.

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[1] Marsh, C. D. Part I of this bulletin, p. 37.

[2] Mendel, L. B., and Sicher, D. F. The Excretion of Barium. American Journal of Physiology, vol. 16, 1906, p. 151.

Similar extracts of alfalfa may also cause death of rabbits in similar dosages.

The acetic-acid extracts of the ash of such barium-yielding plants from the Western States as were examined contain at most but minute traces of barium.

PROTOCOLS.

EXPERIMENT No. 1.

Astragalus arizonicus Gray; type specimen (Tm. 721) deposited in the economic herbarium; collected March 30, 1908, on hills east of Nogales, Ariz. Of the air-dry plant, 500 grams were ground in a drug mill and thoroughly percolated with chloroform water till the extract was a light straw color. The undissolved residue was digested for six hours at 38° to 40° C. with artificial gastric juice in the presence of chloroform toluol. The liquid was filtered off and after being neutralized was combined with the percolate. The undissolved residue was digested six hours with trypsin in 0.2 per cent sodium carbonate, in the presence of chloroform and toluol. This liquid was also neutralized and combined with the percolate. The combined extracts were then concentrated in vacuo to 375 cubic centimeters and carefully neutralized with sodium carbonate. The concentrated extract contained a precipitate in suspension.

January 19, 1909. After stirring so as to suspend the precipitate in it evenly, 40 cubic centimeters of the liquid were fed, at 4 p. m., to a rabbit weighing 1,475 grams.

January 20. The rabbit had severe diarrhea and passed much urine during the night. At 12.20 p. m. it was fed 50 c. c. of the liquid. At 12.45 it was dead. The total amount fed corresponded to 130 grams of plant. The autopsy at 3.45 p. m., showed the stomach distended; its vessels were injected, mainly at the lesser curvature. The greater part of the mucous membrane was only moderately congested; the congestion was considerable only at the fundus. No ulcers. Just beyond the pylorus the small intestines were moderately congested; otherwise normal, except about the middle of the ileum, where some congestion and several hemorrhages were found. One hemorrhagic spot on colon.

EXPERIMENT No. 2.

Astragalus thurberi Gray: type specimen (Tm. 807) deposited in economic herbarium; collected at Patagonia, Ariz., April 6, 1908. Of the air-dry plant, 500 grams were ground, percolated, and extracted as in experiment No. 1. The extracts were concentrated to a volume of 225 cubic centimeters and made slightly alkaline with sodium carbonate.

January 27, 1909. A male rabbit weighing 1,700 grams was fed 40 cubic centimeters of the extract without apparent effect.

January 28. The rabbit weighed 1,590 grams. Again fed 40 cubic centimeters. No marked symptoms.

January 29. The rabbit weighed 1,449 grams. Fed 50 cubic centimeters. Effect about as on previous day. No serious symptoms.

February 2. Rabbit weighed 1,560 grams. The animal was fed 50 cubic centimeters; soon moribund, apparently paralyzed, but reacted to stimuli. It died in 50 minutes, having a terminal convulsion. Autopsy three hours after death showed intestines much distended with gas. There seemed to be an abundant secretion of fluid in them. The stomach contained much mucus and a few semisolid fecal pellets. Mucous membrane much congested at the great and less so at the small curvature. Pylorus free from congestion. Some small hemorrhages in the congested areas. No ulcers.

EXPERIMENT No. 3.

Of alfalfa collected 30 miles south of Hugo, Colo., 500 grams were ground and extracted as in the previous experiments. The evaporation of the extract in vacuo had to be abandoned because of foaming. It was therefore evaporated on the water bath to a thin sirup. The extract was then neutralized with sodium carbonate. It was so acid that some of it was lost because of the foaming. It was warmed on the water bath to drive off dissolved carbonic acid. The solution remaining had a volume of 200 cubic centimeters.

February 10, 1909. Fifty cubic centimeters were fed to a large rabbit. The animal soon seemed uncomfortable, breathed rapidly, lay stretched out, and urinated profusely. In an hour these symptoms had passed off and the animal seemed normal, though quiet.

February 11. The feeding was repeated with the same effect.

EXPERIMENT No. 4.

Astragalus diphysus Gray; type specimen (Tm. 907) deposited in the economic herbarium; collected 10 miles east of Jerome Junction, Ariz. Of the air-dry plant 500 grams were extracted as in experiments Nos. 1 and 2. The combined extract was concentrated in vacuo to 250 cubic centimeters.

February 23, 1909. Of the concentrated neutralized extract 45 cubic centimeters were fed in the afternoon to a large rabbit.

February 24. A like amount fed in the forenoon. The rabbit seemed somewhat prostrated. A third similar dose fed in the afternoon. Death in 90 minutes. No autopsy.

EXPERIMENT No. 5.

An extract of 500 grams of alfalfa, collected 30 miles south of Hugo, Colo., was prepared as in experiment No. 3. About half of the resulting sirup was fed August 30, 1909, to a rabbit weighing 1,885 grams. The animal urinated much and passed some feces. It died in 3½ hours. No autopsy.

EXPERIMENT No. 6.

September 1, 1909. A rabbit weighing 1,880 grams was fed 50 cubic centimeters of the extract used in experiment No. 5. It urinated, passed some feces, and was dead in 2¾ hours. On autopsy the intestines were found almost empty. The stomach was much injected; at the fundus its mucous membrane was congested and inflamed and showed two small ulcers; the pyloric end was free and pale. Heart not dilated; full of clot on both sides.

EXPERIMENT No. 7.

An extract was made from 500 grams of *Aragallus lamberti* (Pursh) Greene (collection No. 8.96) from Hugo, Colo. The extract was neutralized and concentrated in vacuo to 150 cubic centimeters. On July 25, 1909, 90 cubic centimeters were fed to a rabbit weighing 1,485 grams. Death in two hours. The remaining 60 cubic centimeters were analyzed and yielded only 0.0031 gram barium sulphate. The residue of the plant was also analyzed and shown to contain a larger percentage of barium than before extraction. (Cf. Table VII.)

EXPERIMENT No. 8.

A quantity of 400 grams of alfalfa (collection No. M. 90) was ashed in platinum. The ash was extracted with dilute acetic acid and the extract evaporated to dryness in porcelain. The residue was a white, crummy mass. It was heated to 150° C. in the oven to remove any remaining traces of acetic acid. It was then treated with 150 cubic centimeters of water. A small part remained undissolved, so that the liquid was milky in appearance.

September 2, 1909. Fifty cubic centimeters of this milky suspension were fed at 11.15 a. m. to a rabbit weighing 2,250 grams. The animal breathed rapidly, lying on its side with hind legs extended. It soon urinated, sitting up for the purpose and then lying down again. The effects gradually passed off, so that by 1 p. m. it seemed normal. Did not eat. At 2.45, 60 c. c. were fed. For a time this did not seem to have much effect, but at 4.30 p. m. the rabbit was lying on its side prostrated. It passed some feces, but not very much. At 5.10 p. m. it was hardly able to raise its head or move its hind legs. Breathing rapid and shallow. At 5.15 respiration ceased. The heartbeat could still be seen and felt for a time after respiration had ceased. The amount of extract fed corresponded to the ash of 210 grams of plant. It was distinctly alkaline.

Autopsy, September 3. The abdominal cavity contained about 50 c. c. of bloody serous fluid. Animal pregnant. Bladder empty and contracted. Spleen normal. Stomach very large, filled with puttylike food mass, except at pyloric end; mucous membrane of greater curvature, a livid purple, and greatly congested; a few slight erosions; very little autolysis; two distinct hemorrhagic areas, each the size of a small pea.

EXPERIMENT No. 9.

An acetic-acid extract was made of the ash of 300 grams of *Aragallus lamberti* (Pursh) Greene, collected at Hugo, Colo., in the manner described in protocol of experiment No. 8. The volume of the extract was about 100 c. c.

November 28, 1909. Half of this extract was fed at 12.20 p. m. to a rabbit weighing 2,050 grams without producing much effect. The remainder was fed at 5.15 p. m. without much effect. The next morning the animal was apparently normal, but had lost a little weight.

EXPERIMENT No. 10.

An extract was made of the ash of 300 grams of the same plants as in experiment No. 9. The volume of the extract was 100 c. c.

December 4, 1909. Fifty cubic centimeters of this extract were fed at 11.30 a. m. to a rabbit weighing 2,170 grams; the remainder at 2.30 p. m., without serious ill effects. The next morning the animal was apparently well and weighed 2,050 grams. The calcium content of this extract was determined and proved to correspond to 8.5 grams calcium acetate.

EXPERIMENT No. 11.

December 11, 1909. An extract was made in the usual way of 500 grams *Astragalus mollissimus* Torr. (collection No. M. 9.45), from Hugo, Colo. The concentrated extract was made distinctly alkaline with sodium carbonate, producing a heavy precipitate. The volume of the extract, precipitate and all, was 200 c. c. It was then centrifugated and the liquid poured off from the precipitate. The precipitate was suspended in water and about half of the suspension fed to a rabbit of 2,050 grams at 11.30 a. m. without much effect. At 4.30 p. m. the remainder was fed, but the rabbit was apparently in good condition the next day, weighing 2,000 grams.

December 12, 11.30 a. m. Fed 50 c. c. of the decanted liquid. In the early afternoon the animal was weak; at 4.30 p. m. very weak, not able to sit up or to hold head erect; lay flat on stomach; at 4.45 p. m. very weak; lay on its side, breathing rapidly; but heart action was good; nose and leg muscles twitched a good deal. At 5.10 p. m.: Convulsive movements of hind legs; an attack of opisthotonos. At 5.20: Opisthotonos for a few moments. At 6.20: Very feeble. At 8 p. m.: Dead in opisthotonos. Rapid onset of rigor mortis.

Autopsy: Stomach rather small; not very congested; contained gas; contents slight, containing a little mucus; mucous membranes only slightly congested; pylorus contracted. Right lung very congested, especially lower lobe. On cutting open the bronchi a clot was found in lower portion of right bronchus. As the animal had been lying on its right side in moribund condition from 6.20 p. m. to 8 p. m., the condition of the lung may have been hypostatic congestion, though there is the possibility of the beginning of a foreign-body pneumonia.

Experiment No. 12.

December 13, 1909. At 12 m. fed 50 c. c. of same liquid which had been decanted from the extract in experiment No. 11 to a rabbit weighing 1,225 grams. At 4.30 p. m. the remainder of the decanted liquid was fed. Not much effect. The animal died a week later of an acute febrile disease. At this time there was an epidemic among our rabbits. Hence the possibility that the rabbits of this experiment and of No. 11 died of disease must be considered.

Experiment No. 13.

December 22, 1909. A quantity of 250 grams *Aragallus lamberti* (Pursh) Greene was ashed and an acetic-acid extract made in the usual way. The *Aragallus lamberti* used contained barium. The extract had a volume of 55 cubic centimeters. It contained, as in the other cases, a certain amount of insoluble material in suspension and had an alkaline reaction. Fed 40 cubic centimeters to a rabbit weighing 1,512 grams without much effect. On December 23 the rabbit weighed 1,260 grams. The extract fed contained 8.5 grams calcium acetate.

Experiment No. 14.

December 29, 1909. An extract of 600 grams of *Aragallus lamberti* (Pursh) Greene (collection No. M 8.98) was made in the usual way. It was concentrated and made quite alkaline with sodium carbonate. The precipitate thus formed was removed by centrifugation, and half of it, suspended in water, fed to a rabbit of 1,260 grams. No visible effect.

December 31: Weight of rabbit 1,225 grams.

Experiment No. 15.

December 31, 1909. Fed 50 cubic centimeters of the liquid decanted from the precipitate fed in experiment No. 14 to a rabbit weighing 1,375 grams without producing any serious effect. The amount fed corresponded to about 250 cubic centimeters of dry plant deprived of the precipitate formed by the sodium carbonate.

Experiments 14 and 15 were made because it was thought that there was some evidence that when the concentrated extracts were made alkaline with sodium carbonate most of the toxic material was precipitated. As this experiment shows, this idea was erroneous. By making alkaline, the calcium and probably any traces of barium that may have been present were precipitated as the carbonate. Calcium carbonate is but slightly if at all toxic. This treatment, viz, converting the calcium into an insoluble form, may have rendered the extract nontoxic. Experiments of a somewhat analogous nature are described in protocols Nos. 11 and 12.

EXPERIMENT No. 16.

November 8, 1909. At 12.15 p. m. fed 50 cubic centimeters of water containing in solution 2.5 grams anhydrous calcium chlorid to a white rabbit weighing 2,060 grams. No effects were noticed, and at 2 p. m. the dose was repeated. In all, 5 grams calcium chlorid were fed, or 2.94 grams per kilo of body weight. The rabbit lay on its side a while and urinated a good deal, but these were the only effects noted.

EXPERIMENT No. 17.

November 11, 1909. At 2.30 p. m. a brown rabbit weighing 1,915 grams was fed 48 cubic centimeters of a 9.5 per cent aqueous solution of anhydrous calcium chlorid, or 2.5 grams per kilo of body weight. The rabbit urinated as soon as it was put back into its cage; respiration was very rapid. At 3.50 p. m. the animal seemed normal. At 3.55 p. m. it urinated again. At 4.30 p. m. it still seemed normal. The dose was repeated, making the total amount of calcium chlorid fed 5 grams per kilo of body weight. At 5.45 p. m. the animal did not seem very sick; it did not eat, but was quiet.

The next morning the rabbit was found dead, lying flat on its belly, its hind legs drawn up under it as though it had collapsed without a struggle; body limp; no rigor; no bloating. On opening the abdomen some 25 to 50 cubic centimeters of serous fluid were found in the peritoneum. The intestines were not bloated. The stomach was large and prominent, the fundus being distended, congested, and very much reddened; the congestion of the fundus was greatest on the ventral side at the greater curvature, as though due to the accumulation in this place by gravity of the liquid fed. On opening the stomach it was found filled with partly digested food and considerable liquid; the mucous membrane of the ventral side in the region of the greater curvature of the fundus was filled with hemorrhages, eroded, and ulcerated; the pyloric end was nearly normal. The upper end of the small intestines was somewhat injected, but showed neither hemorrhages nor ulcers. The colon was also injected. The liver was congested. The heart was contracted. The lungs were normal.

EXPERIMENT No. 18.

November 24, 1909. At 11.30 a. m. a brown rabbit weighing 1,885 grams was fed 50 cubic centimeters of a 7.5 per cent aqueous solution of anhydrous calcium chlorid. There were no marked effects, so the dose was repeated at 5.15 p. m. Altogether, 3.98 grams calcium chlorid per kilo of body weight were fed. The second dose did not seem to affect the animal much. It seemed well the next morning and was eating. On November 26 it weighed 1,715 grams.

EXPERIMENT No. 19.

November 26, 1909. A brown rabbit weighing 1,715 grams was fed the extract prepared by digestion according to the method used by Crawford from 250 grams of *Astragalus nitidus* Dougl. collected at Woodland Park, Colo. The extract was administered in two doses on the same day, one in the forenoon, the other in the afternoon. Soon after the second dose the animal began to become weak and later had a few clonic spasms of the hind legs, which became partially paralyzed later, and the animal died about 6 p. m. without a struggle. On autopsy nothing was found except a highly inflamed and somewhat corroded condition of the fundus of the stomach.

EXPERIMENT No. 20.

October 20, 1909. A quantity of 225 grams of soy beans from Pittsville, Va., was ground and extracted in the usual way. The extract was concentrated on the water bath to a volume of 250 cubic centimeters.

Of this carefully neutralized extract, 75 cubic centimeters were fed at 4.30 p. m. to a rabbit of 2,010 grams. No effects whatever were noted. The next day at 9.30 a. m. 100 cubic centimeters were fed, with no effects whatever beyond some diuresis. The rabbit lost but very little weight. The total extract fed was equivalent to 157 grams of air-dried plant.

EXPERIMENT No. 21.

October 14, 1909. Fed 33 cubic centimeters of a colloidal solution of barium sulphate to a rabbit weighing 2,060 grams; no visible effect. October 15: Fed 50 cubic centimeters of the same solution; no effect. October 16: Fed 50 cubic centimeters of the same solution; no effect. In all, 6.5 grams barium sulphate were fed. The colloidal barium was prepared according to the method of Feilmann, casein freshly prepared from milk being used as the protective colloid.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 247.

B. T. GALLOWAY, *Chief of Bureau.*

A KNOT OF CITRUS TREES CAUSED BY SPHAEROPSIS TUMEFACIENS.

BY

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 29, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "A Knot of Citrus Trees Caused by Sphaeropsis Tumefaciens," by Miss Florence Hedges, Assistant Pathologist in the Laboratory of Plant Pathology, and Mr. L. S. Tenny, formerly Assistant in Plant Pathology, and to recommend its publication as Bulletin No. 247 of the series of this Bureau.

This paper deals with an infectious disease of citrus trees which has caused extensive losses in Jamaica, British West Indies. The same or a very similar trouble has recently been discovered in the United States.

The investigations reported herein have extended through a period of six years, during which time the cause of the disease has been established beyond a doubt by means of repeated inoculations, reisolations, and reinoculations.

The authors desire to acknowledge the courtesies shown them and assistance rendered by Hon. William Harris and Hon. William Fawcett, director and former director, respectively, of Public Gardens and Plantations, Kingston, Jamaica; Hon. William Cradwick, Department of Public Gardens and Plantations, Jamaica; Hon. Mr. Cousins, in charge of the Government laboratory; the late Mr. J. A. Stephens, of Radnor; Rev. J. G. Hall, Mr. George Costa, Mr. Edwards, and Mr. Malcolm, Jamaica, British West Indies.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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NOTE.—The photographs and most of the drawings illustrating this bulletin are the work of Mr. James F. Brewer, artist, Laboratory of Plant Pathology.

B. P. I.—733.

A KNOT OF CITRUS TREES CAUSED BY SPHAEROPSIS TUMEFACIENS.

INTRODUCTION.

The fungus under discussion in this paper was first isolated in 1904 from knots on lime trees from Jamaica (Pl. I). Later it was also obtained from orange-tree knots from the same island (Pl. II). Repeated inoculations with both strains and reisolation of the fungus from the knots so produced have proved conclusively its parasitism. Previous to 1911 no such disease, so far as the writers know, had been observed in the United States, but in the spring of that year a knot similar, if not identical, was received from Florida.[1] No reference to the disease, either in this country or elsewhere, has been found in literature. A short preliminary account of the disease with a description of the fungus has been published.[2]

In 1906 one of the writers (Hedges) visited several of the larger Jamaican "pens" (estates) on which limes and oranges were cultivated, for the purpose of studying the disease in the field. It was found, however, that although in previous years the disease had caused much trouble in the northern and western parts of the island, the majority of the growers had been able to keep it under control by cutting and burning and no longer considered it very serious.

---

[1] In May, 1911, a knot on a lime twig was received from Quay, Fla. It resembled the Jamaican knot and was thought to be due to the same cause. In response to inquiry the sender wrote as follows: "I do not find any other growth than the piece which you have. This tree was on the place when I purchased it in 1908. I judge the tree to be about eight years of age. It has always been healthy until this last year, when it showed disease, as evidenced by numerous dead branches. These I am pruning out."

Mycelium resembling that of *Sphaeropsis tumefaciens* Hedges was present in the bark and wood of the knot and also in black streaks in the wood of the stem below the knot. The fungus was isolated from both knot and stem by the method employed for the Jamaican knot.

Inoculations were made on lime twigs and branches with a freshly isolated culture (13 days), and these have been under observation for seven months as this bulletin goes to press. Three of the inoculated shoots were killed, and although no real knots have formed on the others, considerable tumor tissue has been produced and mycelium is present in the tissues. There has been a large production of gum in every case.

On corn meal, however, the only medium on which the fungus has fruited, the spores are larger and thicker walled than any of those of *Sphaeropsis tumefaciens* that have been observed thus far. They measure 28 to 36 μ by 11 to 16 μ, and when they become colored they are a decided brown instead of yellow. By no means do they always become brown, however. No 2-celled spores have been observed.

[2] Hedges, Florence. Sphaeropsis Tumefaciens, Nov. Sp., the Cause of the Lime and Orange Knot. Phytopathology, vol. 1, no. 2, 1911, pp. 63-65.

Mr. George Costa, of Orange Valley, St. Anns, who had watched the disease for several years and whose groves had suffered extensively from it, made the following statements regarding it:

1. It attacks trees of all ages, old as well as young wood.
2. Knots appear in any season, regardless of weather conditions.
3. The disease spreads from one tree to another.
4. If an affected tree is cut down, the young shoots coming up from the roots develop knots.
5. From the knots an abnormal number of branches spring (witches'-brooms).
6. An affected tree has a whole series of knots extending up the branches, not simply a few isolated ones.
7. An affected tree may live about 18 months,[1] but always dies prematurely as a result of the disease.
8. Trees growing in the so-called "red dirt," which is rich in iron, are more often attacked.

At the time of the writer's visit there were no badly diseased trees in Orange Valley. The disease, which had formerly been very prevalent there, seemed to have been held in check by the severe pruning. There were scattered knots, however, and specimens of these were brought to Washington.

DESCRIPTION OF THE KNOTS.

The knots vary in size from three-eighths of an inch to 2 or 3 inches in diameter. Generally they are approximately round, but in the earlier stages before they surround the stem they have a broad, flattened base and may be somewhat elongated, the longer axis being parallel to that of the infected branch. In some cases, instead of forming a well-defined gall the disease produces an eruption extending several inches along the limb. This consists of slightly raised and variously fissured portions.

At first the incipient knot is covered by the bark, but after some months this usually dies and falls away, exposing the enlarged woody tissues. In the early stages of growth the surface of the knot (the bark) is light colored and rather smooth. With age the surface becomes darker and more or less fissured, and an old gall divested of its bark is often almost black, rough, knotty, and deeply furrowed. When the growth is rapid, however, the malformation may reach a large size and the bark surface still be intact, smooth, and light in color.

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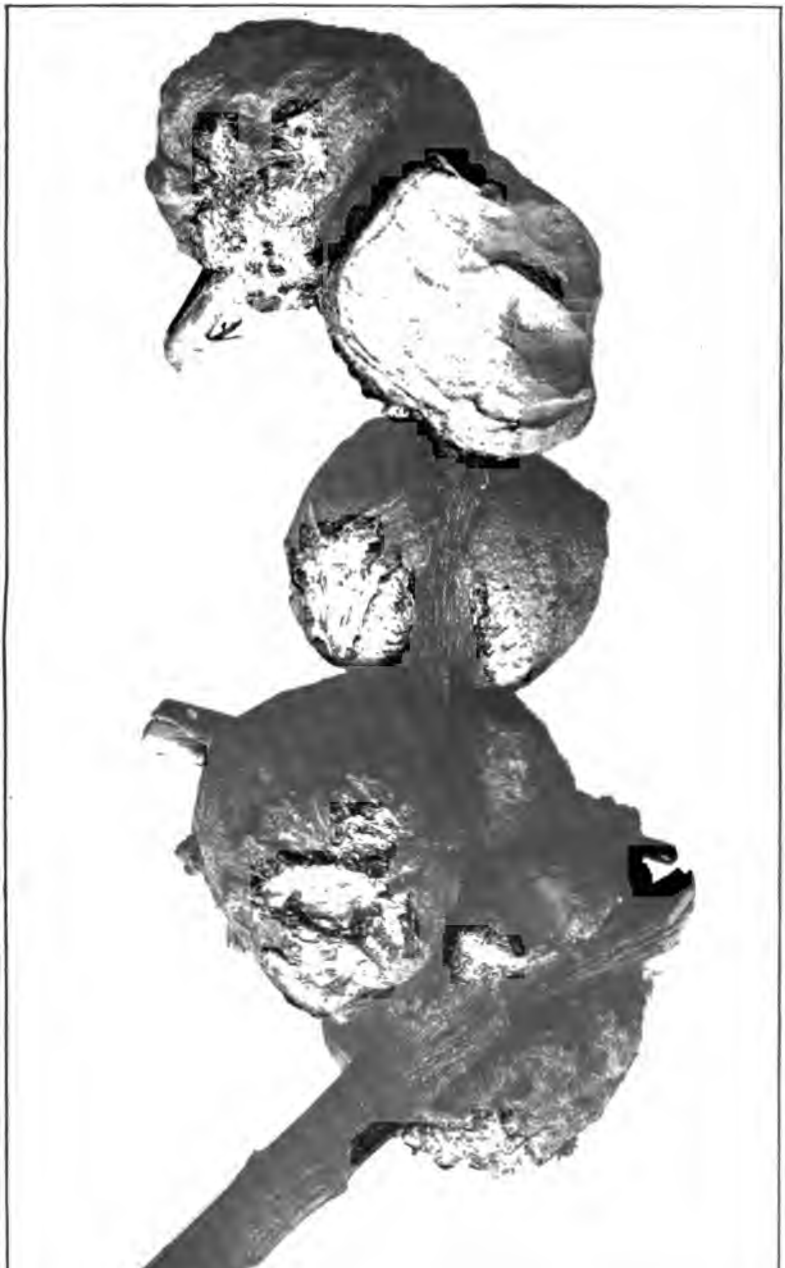
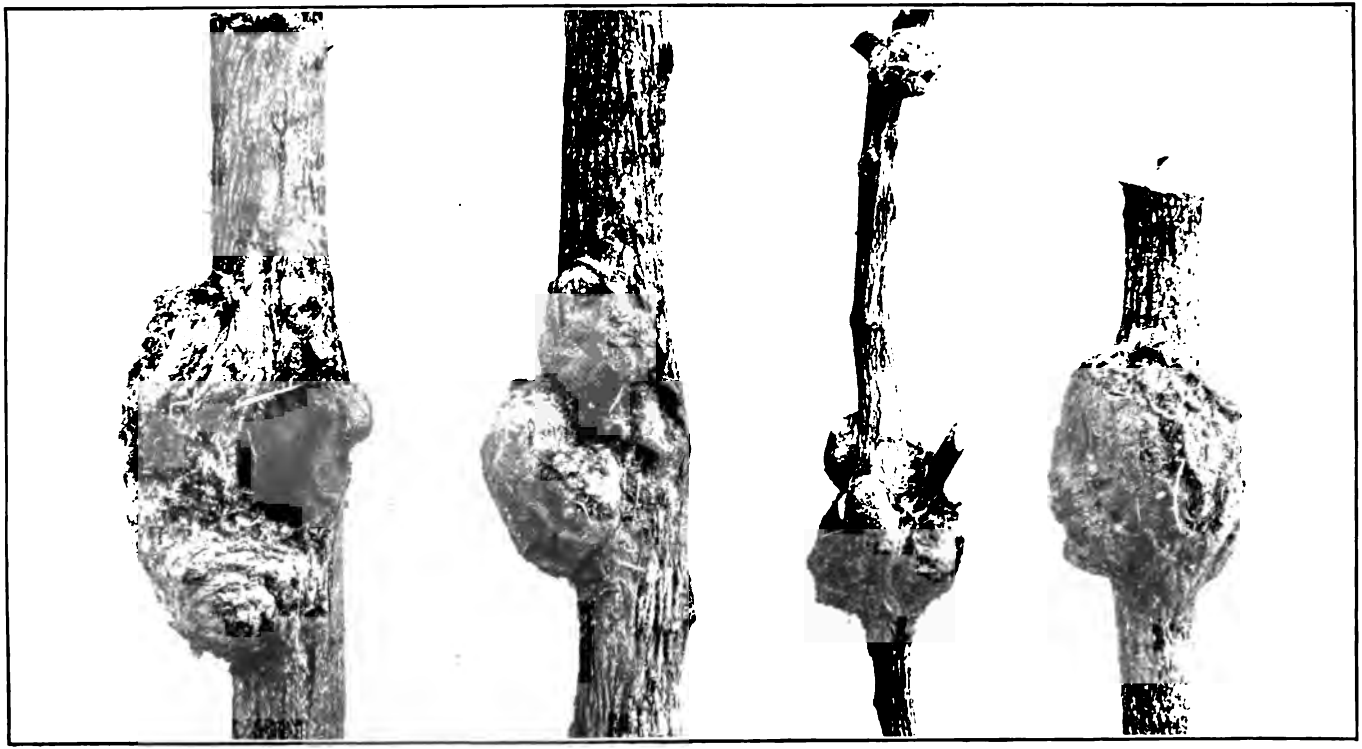
[1] Trees inoculated in the greenhouse in Washington are alive at the end of five years, although in many cases the portions of the branches above the knots have died.



LIME KNOTS RECEIVED FROM JAMAICA IN 1904, ONE OF THEM PARED AWAY TO SHOW THE THIN BARK AND VERY HARD WOODY STRUCTURE.

(Natural size.)



ORANGE KNOTS RECEIVED JANUARY 2, 1909, FROM JAMAICA.
(About natural size.)

The surface of the knot is usually quite different in texture from that of the healthy stem; the firm greenish bark is replaced by a softer, more or less crumbling surface, cutting easily with a knife. The interior of the knot, however, is very hard and compact, being composed of firm woody tissues. The outer layer of the knot (modified bark) is about the thickness of ordinary bark, i. e., the knot grows chiefly by additions to the woody, not to the cortical tissues. The color of the interior of the knot may be similar to that of healthy wood or it may be more or less streaked with black. The knots are attached by a broad base and can not be broken off. As they grow they extend laterally and may ultimately girdle the branch.

The first indication of infection is a slight swelling of the branch. As this increases in size the bark, which at this stage covers the young knot, becomes lighter in color and is noticeably cracked and has a corklike appearance. Growth under greenhouse conditions in Washington is slow, several to many months being necessary for the production of knots 1 to 3 inches in diameter. When many knots appear upon a branch the single ones may be smaller. In the artificial infections in the Department greenhouses it has taken from five months to two years for the knots to girdle the branch and to become 1 to 2 inches in diameter, but our temperatures were considerably lower and the moisture less than in Jamaica. By the time the stem is girdled all of that part of the branch above the knot is usually dead or dying. (Pl. III.) When a tree contains numerous infections, therefore, a large portion of it dies.

A striking characteristic of the lime knot is the growth of a large number of new shoots from the knots, forming typical witches'-brooms (Pl. IV, figs. 1, 2). This did not always take place in the greenhouse inoculations, although it frequently did. Sometimes there were only one or two shoots from the knot, but more often the number was greater, and knots have been observed which bore 30 or 40 small shoots. These shoots grow rapidly, and some of them soon reach a height of several feet with few, if any, branches, and often bear knots. Usually after some months all of these shoots die.

In case the tree has a large number of infections the death of parts beyond the encircling knots results in the loss of the greater part of the tree, and what remains is so weakened as to be of no commercial value. As the disease develops, secondary knots form on the main branches and trunk (Pls. V and VI), often extending to the ground, and the death of the entire tree is the ultimate result.

Gum frequently oozes from the knots, and gum pockets are of common occurrence in the infected wood, but this gummosis is not peculiar to the lime knot.

CAUSE OF THE DISEASE.

This disease is of fungous origin. The facts supporting this statement are as follows:

A microscopical examination of the knots and of the stem above and below the tumors revealed the presence of mycelium in abundance in the cells of all the tissues. It was particularly abundant in the cortex, which was almost a solid mass of black mycelium in some of the orange knots. The wood also contained quantities of it (figs. 1 and 2), and the pith was likewise invaded (fig. 3). Later it was observed that large rapidly growing knots as a rule contained much less mycelium than the smaller slow-growing ones, and usually the greater part of the hyphæ in the former were hyalin. In the young rapidly growing tissues of buds growing out of knots the mycelium is confined to the intercellular spaces (fig. 4).

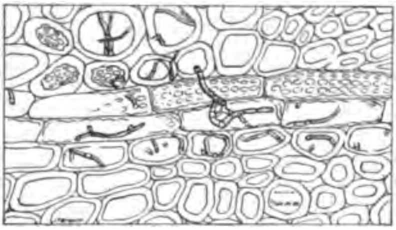


Fig. 1.—Cross section of a lime knot, showing location of hyphæ in wood cells and medullary ray. Stained with haematoxylin and safranin.

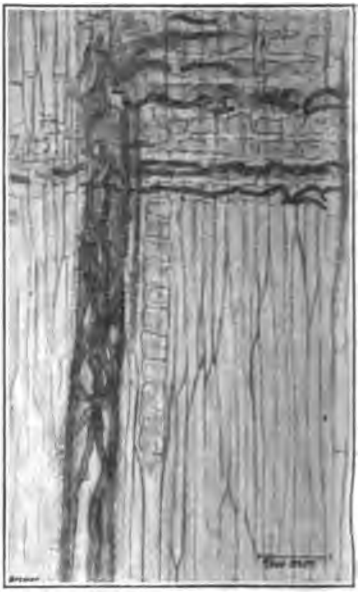
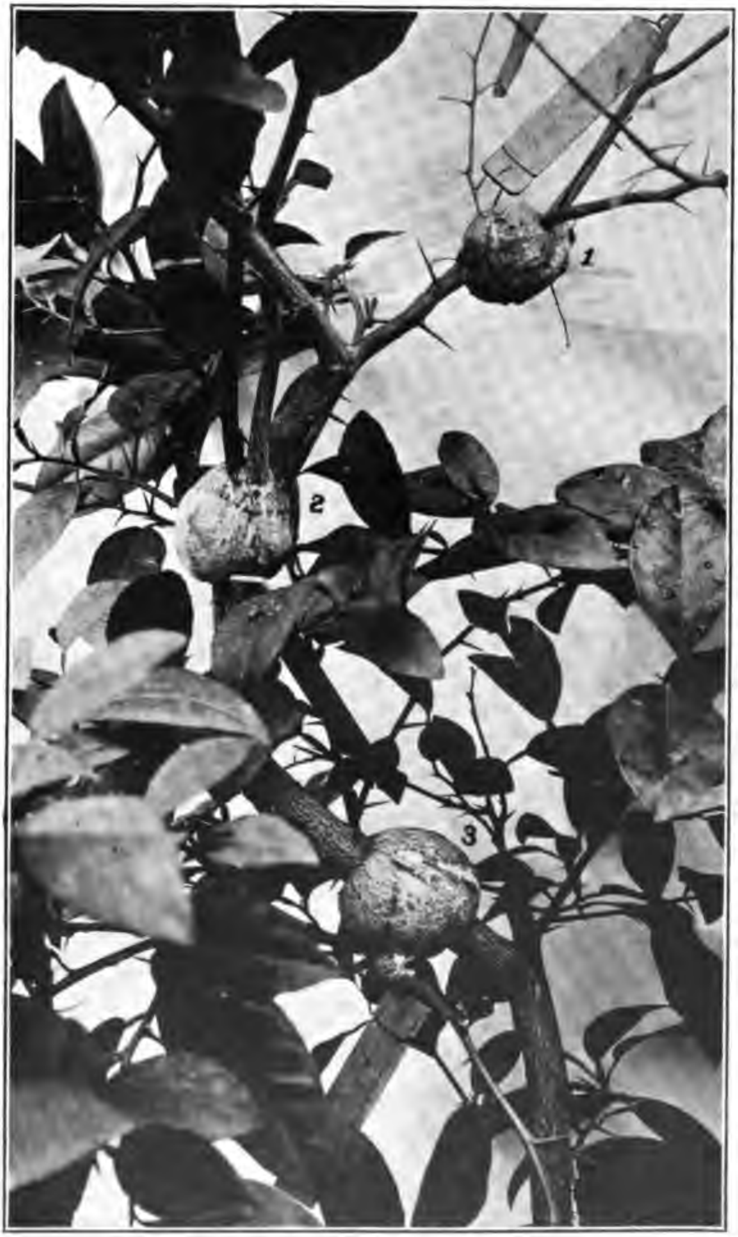


Fig. 2.—Radial section of stem above a knot on orange, showing mycelium of *Sphaeropsis tumefaciens* traversing the wood in various directions. This section was made from a natural infection at a distance of 1 inch above a knot; shows fungus in vessel and medullary ray. Reduced from a camera drawing made with Zeiss 8 mm. objective and No. 12 compensating ocular.

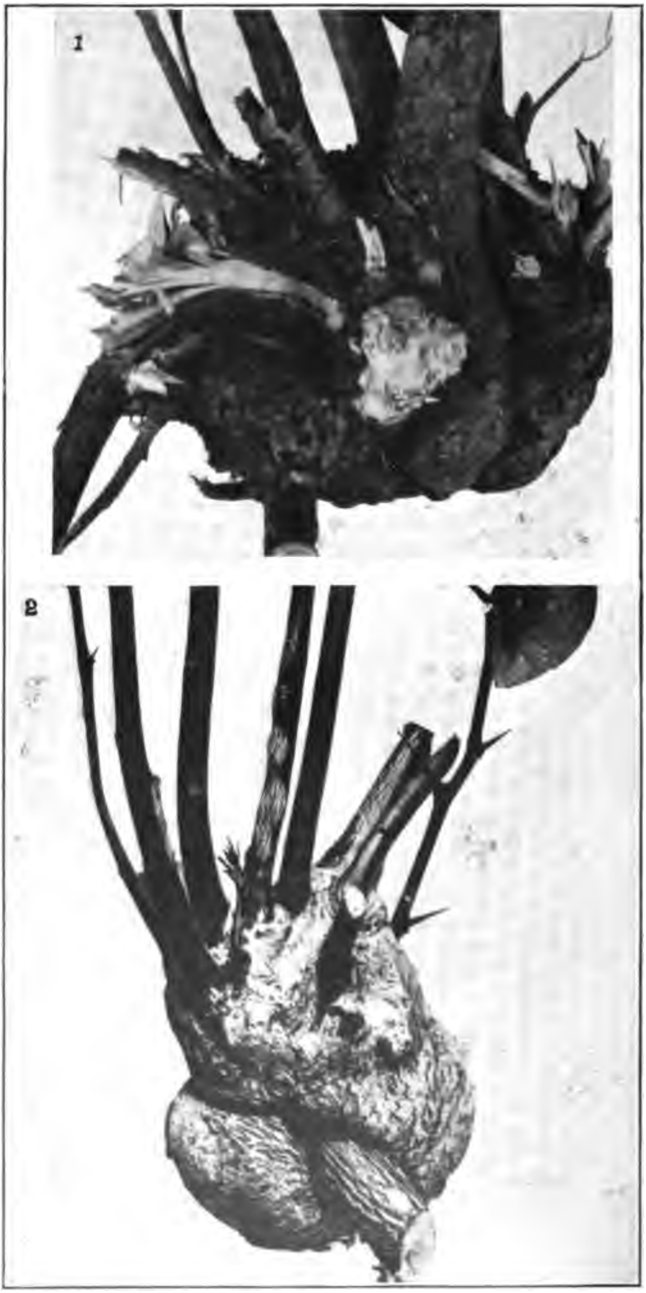
The first isolation of the fungus was made by cutting, under sterile conditions, small pieces of the wood from the interior of the knot and transferring them to tubes of sterile water and beef bouillon. In three or four days pure cultures of the fungus had developed in each tube inoculated, the mycelium pushing out of the interior tissues. Isolations have also been made from the stem above and below the knots. In one instance a pure culture was obtained from the interior of a branch coming out 9 inches above a knot on the main stem.

Using the fungus thus isolated, inoculations made on healthy young trees in the Department greenhouses produced numerous knots resembling in every respect those received from Jamaica. (Pls. III to VI.) From these artificially produced knots the fungus was again isolated and when pure cultures of it were inserted under the bark of healthy



THE FIRST LIME KNOTS PRODUCED BY PURE-CULTURE INOCULATIONS WITH SPHAEROPSIS TUMEFACIENS OBTAINED FROM THE KNOTS SHOWN IN PLATE I.

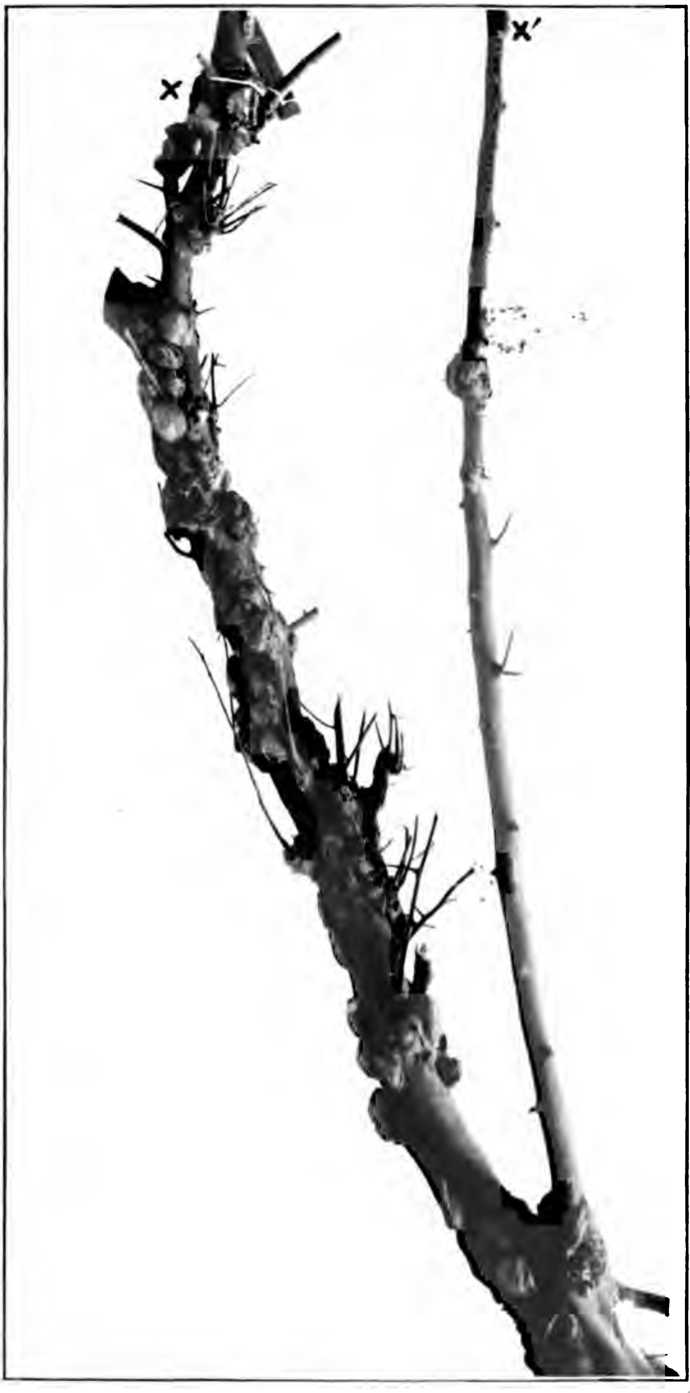
The inoculated branch is much diminished in size between inoculations Nos. 1 and 2, and is dead above inoculation No. 1. Tree I, inoculations Nos. 1, 2, and 3, December 1, 1904. Photographed March 31, 1906. Hothouse, Washington, D. C. (About two-fifths natural size.)



WITCHES'-BROOMS PRODUCED ON LIME TREES BY SPHAEROPSIS TUMEFACIENS.

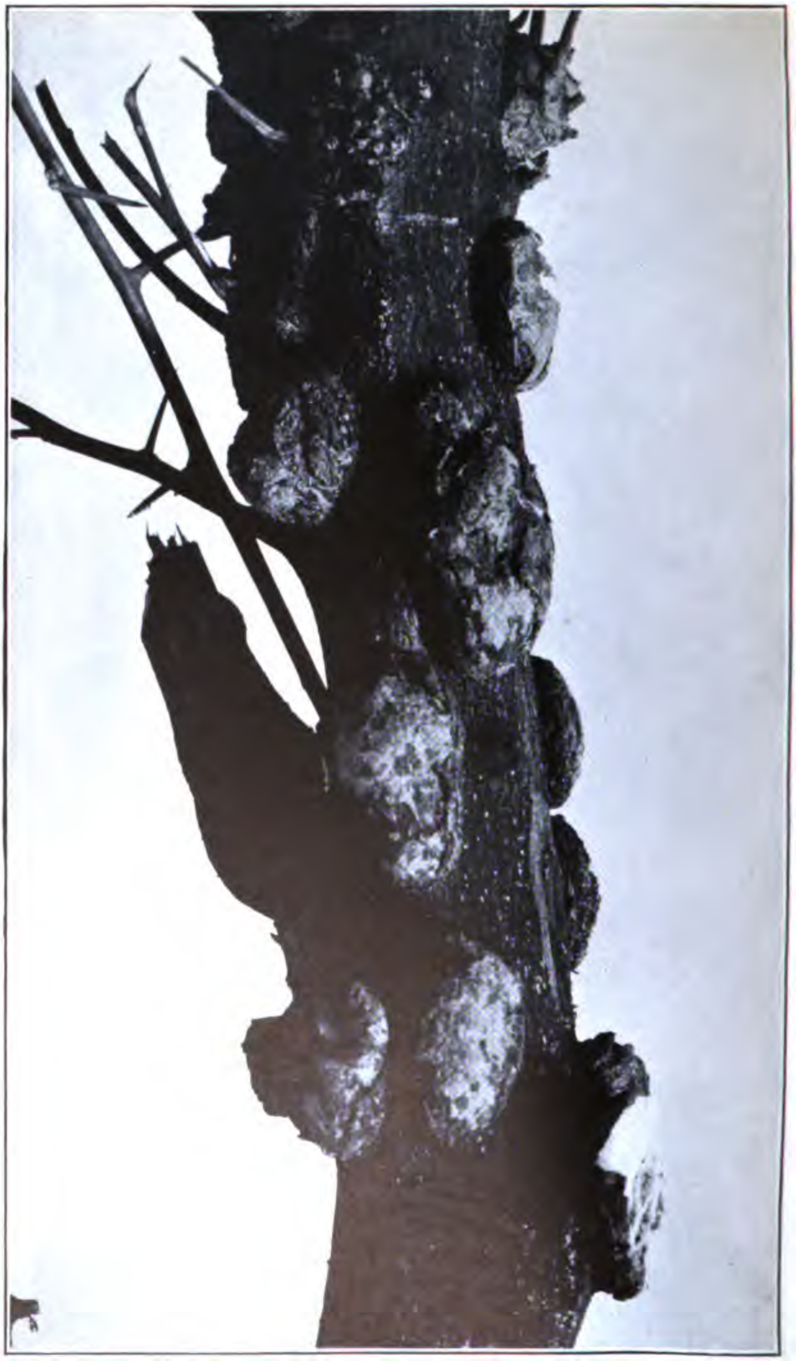
FIG. 1.—Witches'-broom brought from Jamaica in July, 1906. FIG. 2.—Witches'-broom produced by inoculation No. 4, December 1, 1904; eruption extending up the stem in one of the shoots. Photographed December 1, 1905. (Natural size.)

PLATE V.



PORTION OF TREE II INOCULATED AT X (INOCULATION NO. 5), DECEMBER 1, 1904, SHOWING NUMEROUS SECONDARY KNOTS.

The fungus was traced through the stem to X', a distance of 5 feet from the point of inoculation. The infection covers a period of 3 years and 7 months. (About one-fifth natural size.)



PORTION OF TREE II. DETAIL FROM PLATE V. ENLARGED.
(About natural size.)

lime trees more knots resulted. The number of successful inoculations, reisolations, and reinoculations proves beyond a doubt that this fungus is the cause of the disease.

ISOLATION OF THE FUNGUS.

The fungus is easily isolated from the knots. It is preferable to use fresh young knots for this purpose, although the original isolation was made from knots about 3 inches in diameter. In the various isolations made by the writers the knots were thoroughly washed and soaked in mercuric chlorid (1 to 1,000) from three minutes to one hour before cutting out portions of the interior as material for cultures. Three minutes were found to be sufficient. Dipping in alcohol before transferring to mercuric chlorid insures a thorough wetting of all portions by the latter, and this method was usually followed. If the surface of the knot was very rough or cracked, this part was cut away previous to the soaking in mercuric chlorid. After a thorough rinsing in sterile water, the knots were cut in two and portions of the inner tissue were cut out with a sterile knife and dropped into tubes of culture media, preferably sterile water. Pure cultures were obtained in two to three days by this method.

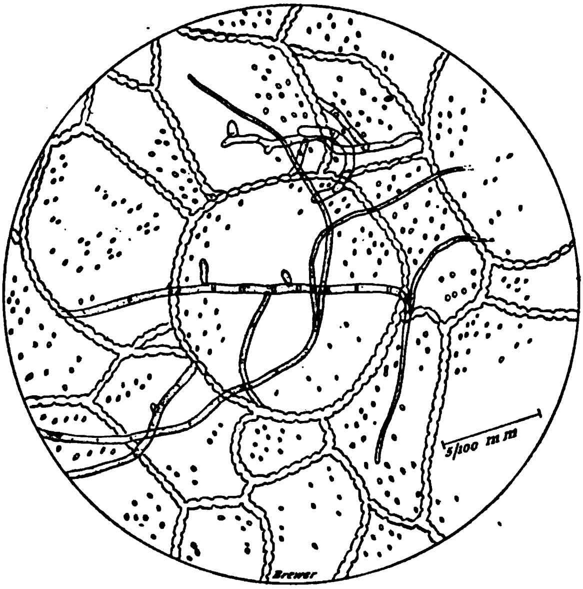


FIG. 3.—Cross section of lime stem, 2¼ inches above a knot, showing mycelium in the pith.

The fungus has also been seen many times in the stem between the knots and has been isolated therefrom. (Pl. VII, fig. 6.)

DESCRIPTION OF THE FUNGUS SPHAEROPSIS TUMEFACIENS.

Mycelium.—Within the host the fungus occurs as a branching, much-septate mycelium, consisting of colorless or brown hyphæ. The colorless young filaments soon change to a pale brown, which at length deepens into a shade so dark that in a mass the mycelium looks black. It is the massing of these old hyphæ which imparts the black color to portions of some of the knots. The color is located in the cell walls. Both the hyalin and brown hyphæ vary a great deal in diameter. (Pl. VIII, fig. 9.) In measurements made of the brown hyphæ in one of the knots the diameter ranged from 2 to 4 μ, and that of the hyalin hyphæ in the same knot from 0.4 to 3.5 μ. Very much coarser hyphæ commonly occur in cultures. (Pl. VIII, fig. 10.) The walls of the hyphæ may be straight or often quite irregular in outline. The tips of the young hyphæ growing from infected wood sterilized externally and put into tubes of sterile water are commonly somewhat swollen. In cultures the very young hyphæ are sparingly septate, but in a few days to many weeks there are usually many coarse brown filaments, which are divided into approximately isodiametric cells, frequently with bulging lateral walls. (Pl. VIII, fig. 9.) Often on artificial media, especially in old cultures, hyphæ occur in which the walls are thickly beset with warts. (Pl. VIII, fig. 8, and Pl. IX, fig. 5.) Sometimes these warts are 2 to 4 μ thick. (See lime-wood cylinders, p. 31.) Fused hyphæ are also common in old cultures. (Pl. VIII, fig. 7.)

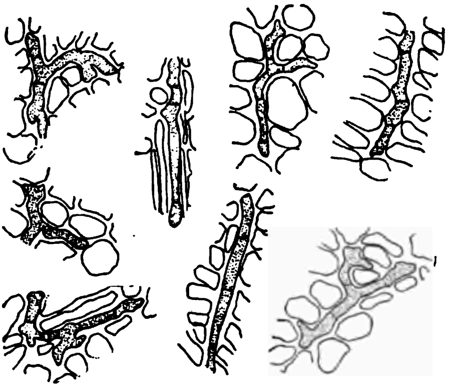
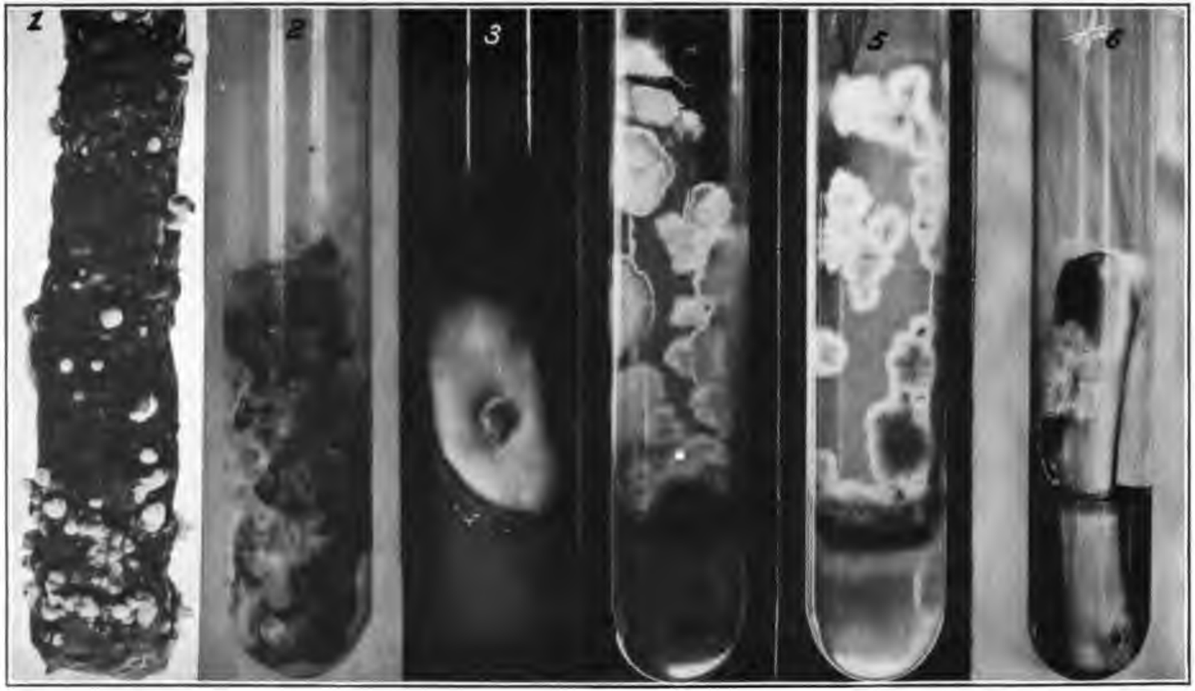


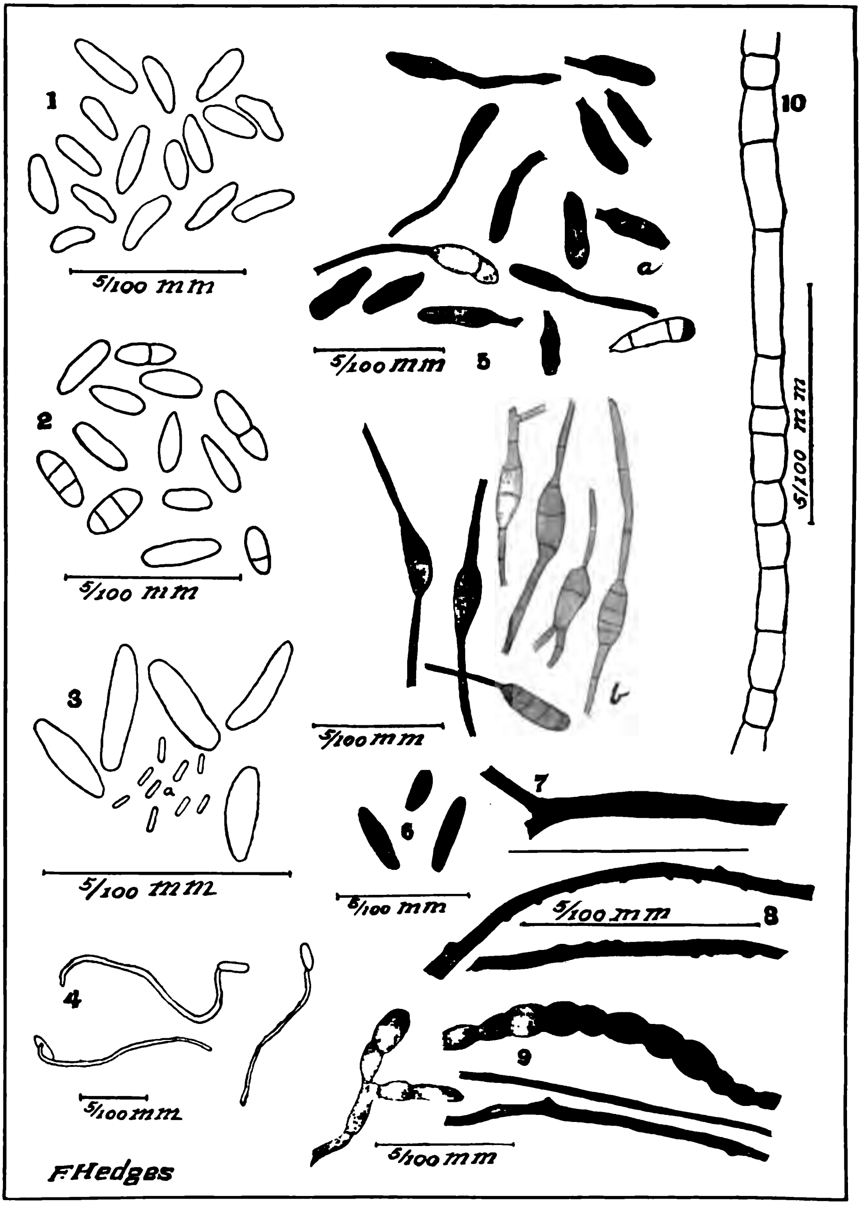
FIG. 4.—Mycelium in intercellular spaces in young, growing tissues. Section made from a bud growing out of a knot.

Pycnidia.—Until the summer of 1909 the fungus was never observed fruiting on the host, either in natural infections or those produced artificially in the greenhouse, nor had it been found producing spores in culture media previous to the spring of that year, although it had been tried in a great variety of media. (See corn-meal cultures, orange strain, p. 19.) However, masses of intertwining hyphæ suggestive of pycnidia in the process of formation (Pl. IX, fig. 6) frequently had been observed. (See prune and beef agars, pp. 22 and 23.) From the first corn-meal cultures containing pycnidia (orange strain) a vigorously fruiting strain has developed. A second (non-fruiting) strain isolated from the orange, however, has never produced spores in cultures, so far as observed, but produces them abundantly on the host. Later a second fruiting strain was isolated from a lime knot produced by inoculation with the fruiting orange strain. The lime strain has thus far fruited very rarely. Spores have been found only in some of the more recent inoculations and in very old cultures (18 months to several years old) and then (i. e., in the cultures) only in very small numbers and not in all the cultures in the same



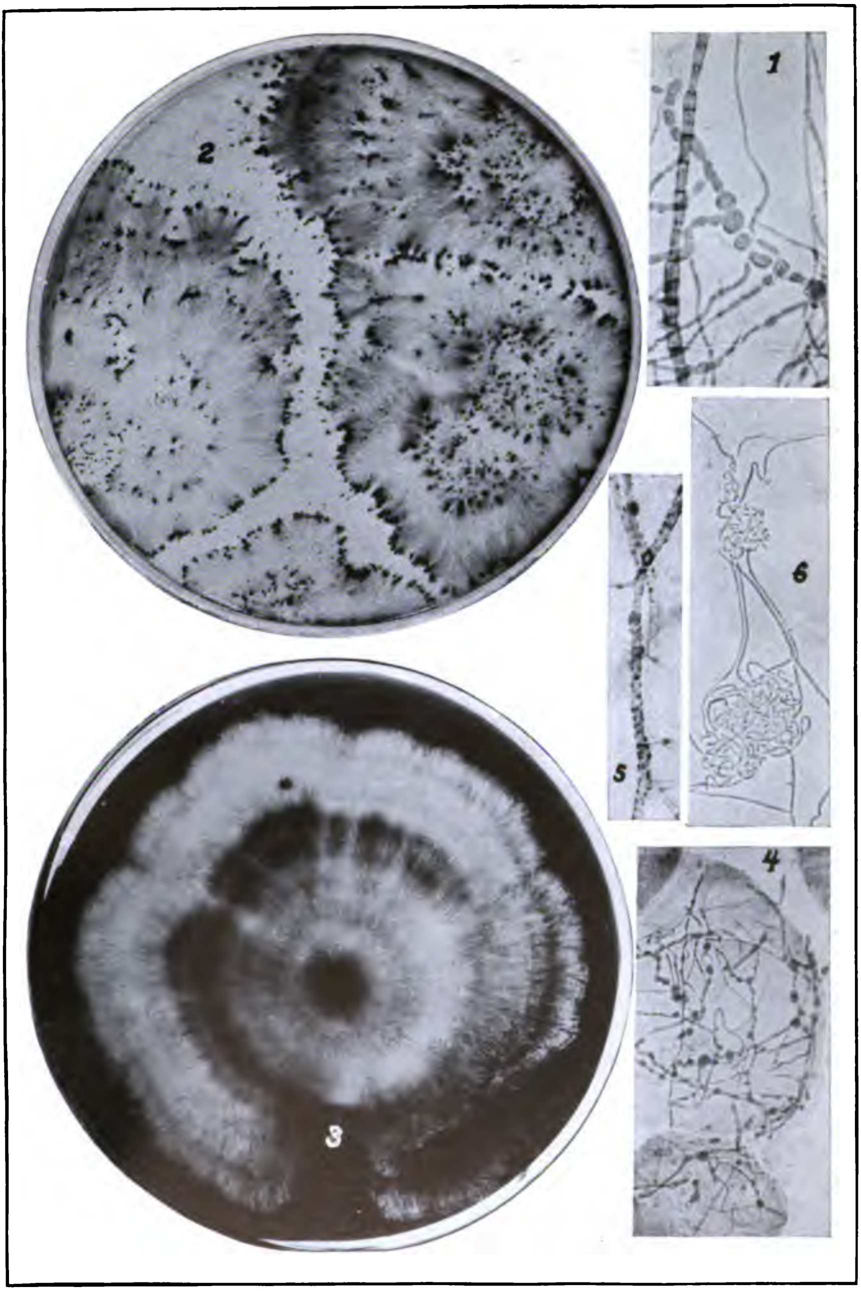
TEST-TUBE CULTURES OF SPHAEROPSIS TUMEFACIENS.

FIG. 1.—Growth on sterilized lime wood, showing the small spherical masses of pseudotissue; 6-weeks-old culture; used for inoculations Nos. 1–6 of December 1, 1904. FIG. 2.—Potato culture 5 weeks old showing stroma. FIG. 3.—Potato culture 3 days old. FIG. 4.—Neutral potato-agar culture 11 days old (lime strain). FIG. 5.—Neutral potato-agar culture 11 days old (orange strain). FIG. 6.—Infected lime stem in sterile water, showing presence of the fungus in the stem between tumors. Surface sterilized by soaking 5 minutes in mercuric chlorid 1 to 1,000. Photographed at the end of 8 days.



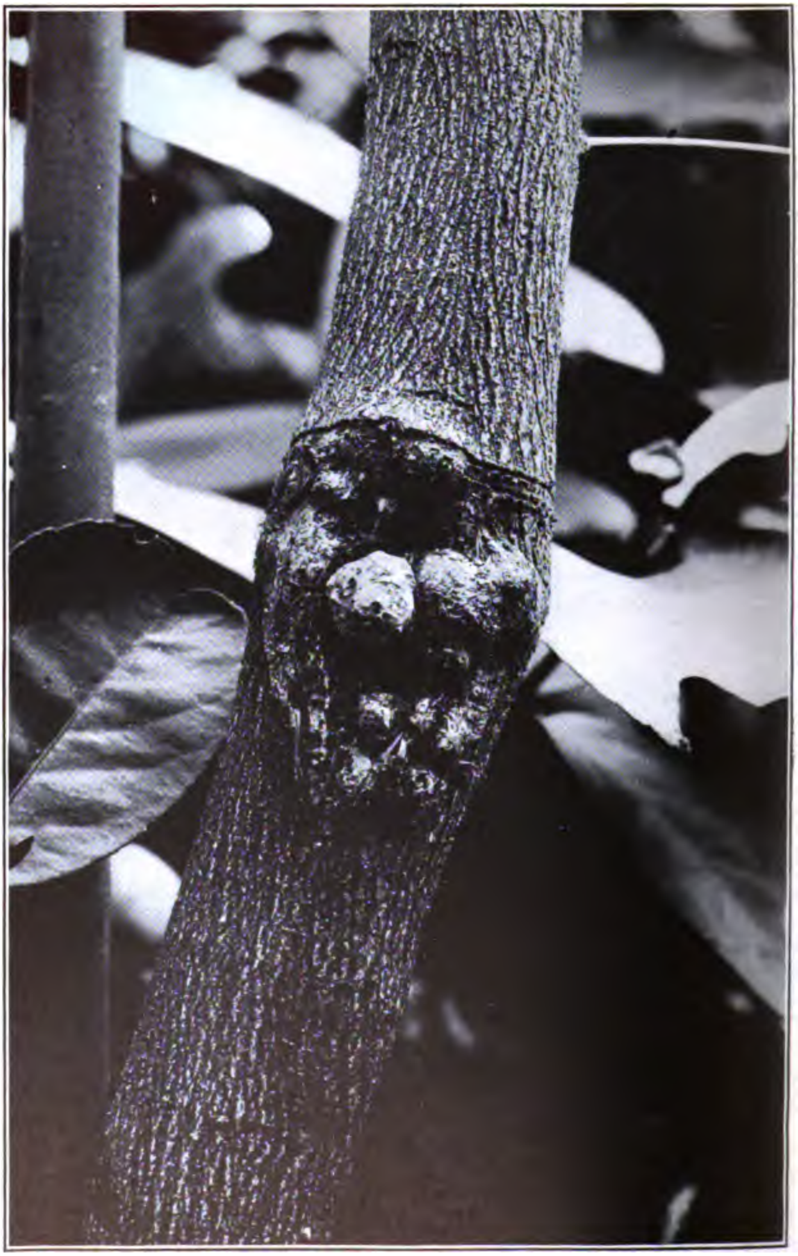
MYCELIUM AND SPORES OF SPHAEROPSIS TUMEFACIENS.

FIGS. 1 and 2.—Pycnospores (orange strain). FIG. 1.—From lime (artificial infection). FIG. 2.—From lemon (raw fruit). FIG. 3.—Pycnospores and spermatia from lime 3 weeks after inoculation (lime strain). FIG. 4.—Germinating pycnospores in potato-agar plate culture, 24 hours old. FIG. 5.—Brown septate bodies. (*a*) Apple (raw fruit, 18 days). (*b*) Steamed potato (6 weeks). FIG. 6.—Yellowish pycnospores on lime 3 weeks after inoculation (orange strain). FIGS. 7, 8, and 10.—Mycelium from potato-agar culture 8 months old. FIG. 9.—Mycelium from corn-meal flask culture 5¼ months old. FIG. 10.—Coarse hyalin hyphæ from potato-agar culture 8 months old.



SPHAEROPSIS TUMEFACIENS ON CULTURE MEDIA.

FIG. 1.—Photomicrograph of swollen hyalin cells in beef-agar plate, 4 weeks old. FIG. 2.—Potato-agar plate, 3 weeks old showing pycnidia. FIG. 3.—Colony 10 days old, on prune agar; inoculation made centrally with a fragment of mycelium. FIG. 4.—Photomicrograph of a fragment of potato cylinder from a culture 3 weeks old, showing the penetration of the cells by the fungus and the nearly complete absence of starch. FIG. 5.—Photomicrograph of mycelium from a beef-agar slant 8 days old, showing protuberances on the hyphæ. FIG. 6.—Photomicrograph of interwoven hyphæ in beef-agar plate, 4 weeks old.



LEMON TREE INOCULATED IN JULY, 1908, BY INSERTING SMALL FRAGMENTS OF FRESH LIME KNOTS (ARTIFICIALLY PRODUCED IN HOTHOUSE) INTO T-SHAPED CUTS UNDER THE BARK. PHOTOGRAPHED JUNE 16, 1909.

(Natural size.)

medium. In the inoculations with the two orange and lime strains on July 21 and 29, 1909, and July 20, 1910 (see pp. 55, 57, 58, and 60), pycnidia have appeared on the host in great numbers (fig. 5). Up to the present time, however, the pycnidia have been found only in the early stages of the disease, when there is very little swelling, i. e., two to four weeks after inoculation, or on old knots (one to two years) which have never developed into good-sized tumors. In the latter case, if the branch beyond the knot is dead, this, too, is sometimes covered with pycnidia.

The pycnidia as they have been observed upon the host (fig. 5) are subglobose, papillate, very dark brown or black, ostiolate, closely crowded together or solitary, with a cellular peridium, and measure 152 to 224 μ by 120 to 192 μ. They are at first covered by the epidermis, sometimes being buried quite deeply in the cortex, but finally they burst through to the surface. They are also occasionally found in the wood. On culture media they are sometimes buried in a stroma (see corn-meal and potato cultures, pp. 20 and 27), in which they occur merely as chambers, separate or confluent, and have no distinct pycnidial wall. Pycnidia in cultures often have short necks.

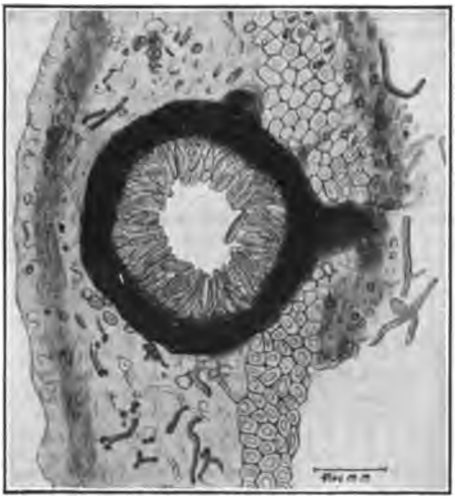


FIG. 5.—Cross section of a lime shoot, showing pycnidium and pycnospores of *Sphaeropsis tumefaciens*, the result of a pure-culture inoculation made July 21, 1909. Stem slightly swollen when collected, August 13, 1909.

Pycnospores.—The spores, both on the host and in cultures, are large, colorless or yellowish, oblong or ovoid, rounded at both ends or subacute, sometimes broadly rounded at one end and quite sharply acute at the other, measuring 16 to 32 μ by 6 to 12 μ, rarely 36 by 8 μ in cultures (Pl. VIII, figs. 1, 2, 3, 4, and 6). They are either long and slender (32 by 8 μ) or broad and short (16 by 8 μ), with intergradings. Often they are slightly curved. On the host they are usually continuous, rarely 1-septate, but in cultures on raw apples and lemon, spores with 1 to 2 septa occur quite frequently (Pl. VIII, fig. 2), and occasionally 4-septate spores have been observed. The spores are cut off singly from long or short threadlike basidia and originate as the swollen end of the basidium. The spores are sometimes discharged in cirri in cultures. This has not been observed upon the host.

Spermatia.—Some time after the appearance of the pycnidia small, cylindrical, colorless, 1-celled, sporelike bodies, the so-called spermatia, are found both in cultures and on the host (Pl. VIII, fig. 3; see corn-meal cultures of the orange strain, p. 20). These are 4 to 8 μ by 1 μ or less, usually 4 to 5 μ long (measurements from corn meal). They may occur in the same pycnidia as the large ovoid spores or in separate pycnidia, the so-called spermagonia. They are cut off from long slender basidia arranged radially. Their germination has not been observed, nor is there any evidence that they function as true spermatia in De Bary's sense of the term.

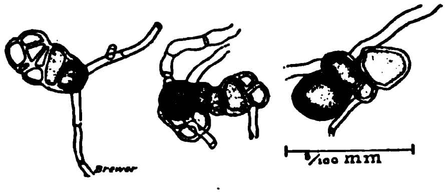


FIG. 6.—Thick-walled, brown chlamydospores from an old pure culture of the lime-knot fungus on banana.

Chlamydospores.—No chlamydospores have ever been observed upon the host, but in old cultures on steamed vegetables or fruit large, thick-walled, intercalary, brown, sporelike bodies are sometimes present in abundance. The most striking of those observed were on banana (see p. 27 and fig. 6). On this medium they were often very large, irregular in shape, and many celled. Their germination has not been observed. All gradations of more or less thick-walled, colorless or brown, coarsely granular, swollen cells, occurring singly or in chains, are common in the mycelium on artificial media (fig. 7 and Pl. IX, fig. 1). (See also cultures on carrot cylinders, p. 28.)

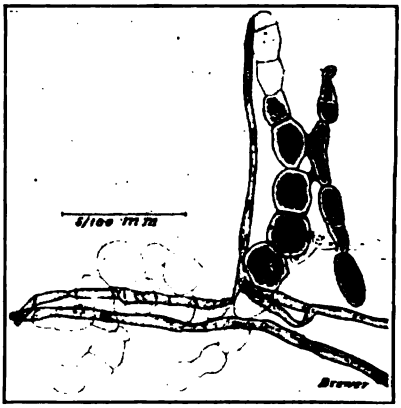


FIG. 7.—Chains of immature chlamydospores of lime-knot fungus from an old pure culture on a carrot cylinder. The majority are colorless.

On steamed prunes (see p. 29) the mycelial filaments break up into one to several celled fragments, which are found germinating freely in cultures about a week old.

Brown septate bodies.—These brown septate bodies[1] have been observed in potato cultures 6 to 52 days old and on apples (the raw fruit) 18 to 31 days after inoculation with *Sphaeropsis tumefaciens* (Pl. VIII, fig. 5). At first sight one would take them for spores—conidia, chlamydospores, or pycnospores, as the case might be. They are found free or attached to the mycelium as terminal or intercalary bodies, in pockets in the tissues (apple) without pycnidial wall, and, rarely, in pycnidia (apple, steamed potato).

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[1] Observed in one instance on the host (lime) and also on lemon (raw fruit) a month after inoculation

Although they often occur in quantities, especially on apple, their presence is by no means constant, and even when there are masses of them, comparatively few are detached from the mycelium. Those which are detached sometimes look as though they had been torn off, and sometimes are rounded off in true spore fashion.

The pycnidia in which they have been found have contained none of the true pycnospores and have shown evidences of more or less disorganization. It is believed that these were old pycnidia into which mycelium had grown and produced there the brown septate bodies. The latter are usually devoid of contents, but this is not always the case. Sometimes one cell is filled with granular contents and the others are empty. Occasionally one of the former is rounded off. These septate bodies have never been known to germinate, and it is not believed that they serve in any way as a means of reproduction. They are in all probability only distorted bits of mycelium.

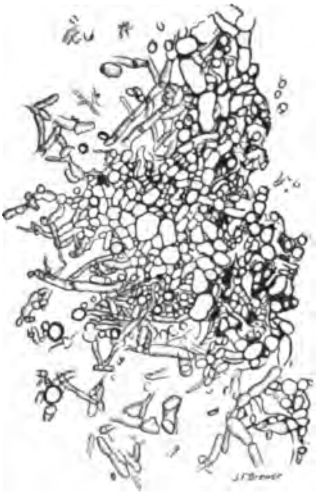

FIG. 8.—Section through one of the cushionlike bodies of *Sphaeropsis tumefaciens* in a pure culture on lime twigs in 2 per cent peptone water. Culture 2 months old; fungus fixed in Carnoy.

Stroma.—On many media, e. g., corn meal and potato (see pp. 18 and 26), the fungus produces a thick, black or yellow, tough, wrinkled stroma[1] (Pl. VII, fig. 2), often covered with little cushionlike elevations or stalklike outgrowths (see p. 19) first noticeable as tufts of aerial hyphæ. They are composed of pseudotissue (fig. 8) and often occur on media on which a stroma is not produced (Pl. VII, fig. 1). (See cultures on lime twigs, p. 31.)

CULTURAL CHARACTERISTICS OF THE FUNGUS.

The fungus grows very well on all of the more commonly used culture media and also on many special media on which it was tried in the hope of obtaining perithecia. The cultures were always kept at room temperature unless otherwise stated. All but the most recent work has been done with cultures descended from isolations from the Jamaican lime knots and in all descriptions this strain is meant unless otherwise stated in the text.

Steamed corn meal.—Corn meal in a 100 or a 1,000-c.-c. flask with sufficient water added to make it thoroughly wet after sterilization is an excellent medium for this fungus. Usually the mycelium has covered the surface of the corn meal with a thin layer of creeping hyphæ in five or six days; few, if any, erect hyphæ. At this age the mycelium may be white or grayish white or it may contain a greater or less proportion of dark hyphæ. The same filament may have colorless and dark-colored portions. Very frequently portions, sometimes nearly the whole, of the fungous layer are pale yellow or buff and wet-shining, suggesting in appearance bacterial growth. Very early in the development of a corn-meal culture (not later than the sixth day in any of the cultures made up to date) a tough stromatic layer begins to form. This is usually black, but portions may be pale yellow or buff. It is coated with short grayish white hyphæ, which by the seventh day have formed a soft, gray, velvety surface layer. There is usually an excellent fluffy marginal growth of erect hyphæ 0.5 to 0.75 cm. long growing on the sides of the flask and later forming a stroma there. In cultures in liter flasks there is often a clear amber-colored exudate after about eight or nine days of rapid growth. The surface of the stroma, smooth at first, in about three weeks becomes very uneven and often much wrinkled. Cultures four weeks old frequently have little cushionlike elevations of the stroma, many of which have been examined for pycnidia, though none have been found in cultures of the lime-knot strain up to this time.

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[1] In potato cultures of the fruiting orange strain (q. v.) which are producing spores in abundance this thick, tough stromatic layer is replaced by a much thinner and more crusty layer, which is easily broken or crushed.

The variation in the color of the stroma probably depends upon the amount of moisture, as the yellow or buff stroma has been observed only when the fungus has been grown in liter flasks or when the 100-c.-c. flasks have been supplied with rubber caps. Bits of yellow and black stroma transferred to liter flasks of corn meal produced a stroma the greater part of which in both cases was pale yellow. This was also true of black stroma from a potato-agar culture which was transferred to a 100-c.-c. flask with a rubber cap. In this case the entire stroma was approximately buff colored without a trace of black. The surface hyphæ remained a pure white without the slightest grayish tinge during the entire time it was under observation (31 days). Transfers from this stroma to 100-c.-c. flasks produced the characteristic black stroma and gray surface hyphæ in seven days in the flask without a rubber cap, while in the flask supplied with the cap there was not the slightest trace of black or gray at the end of 12 days, although a good buff-colored stroma had been produced. When the flasks were examined three days later the cap had split and dropped off and the mycelium had a decided gray tinge. In two 100-c.-c. flask corn-meal cultures inoculated with black stroma from a potato culture there was a very slight grayish tinge in both surface hyphæ and stroma in seven days in the flask with the rubber cap, but the difference between this flask and the check (no cap) was marked. The latter contained the typical black stroma with a coating of gray hyphæ.

Warty hyphæ occur quite frequently in the black stroma (observed in cultures 6 days old), but they are not very abundant. Both dark and colorless hyphæ vary greatly in size and frequency of septa even in young cultures. Aerial hyphæ in a culture 7 days old varied from 2 to 8 μ in diameter. The coarse filaments were many septate, often being divided into isodiametric cells with bulging lateral walls. As the cultures grow older, the hyphæ, both in the surface layer and the stroma, usually become very much distorted and contain many chlamydosporelike swellings. In a culture 5½ months old most of the aerial hyphæ were dark brown, slender, and more or less bristlelike, resembling those in a corn-meal culture of *Lasiodiplodia tubericola* of the same age. There were also some much coarser filaments divided into isodiametric cells with bulging lateral walls. (Pl. VIII, fig. 9.)

Orange-knot strain on steamed corn meal.—Comparative cultures were made of the lime strain and of that isolated from the orange knot in January, 1909. The orange strain made a growth which, though resembling that of the lime strain both macroscopically and microscopically, was much more copious.[1] The orange strain, however, produced pycnidia. The first pycnidia discovered were in flask cultures four months old. The cushionlike elevations of the stroma which had appeared during the first four weeks had increased very much in size, some of them having developed into stalklike outgrowths about 4 mm. high and more or less branched Clavarialike. Many of these were honeycombed with chamberlike pycnidia, all of which with one exception were immature. In one case a pycnidium was found which was filled with large, colorless, one-celled, ovoid spores, but, although a great number of sections were cut, not another pycnidium containing spores could be found, nor did all the stalklike outgrowths contain even immature pycnidial chambers. The cultures were examined from time to time during the weeks following, but it was not until two months later that spores were found again. At this date there were many mature pycnidia, and spores had been discharged in cirri. These cirri were 2 to 3 mm. long and yellowish, but later observations of fruiting cultures show that the spore tendrils are usually pure white when first discharged from the pycnidium. Many of the spores in the cirri were septate (one to two septa) and were germinating. Some of them had put forth two germ tubes. By no means were all of the germinating spores septate, however. Occasionally a spore which was not germinating was found with one or two septa. Rarely a two-celled spore occurred which was slightly constricted at the septum. Two-septate spores were sometimes divided into two small terminal cells and a larger central one. The spores measured 20 to 36 μ by 8 to 12 μ. The majority were about 32 by 8 μ.

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[1] The more luxuriant growth of the orange strain may have been due to the fact that it was a more recent isolation.

In addition to the large ovoid spores these 6-months-old cultures contained in the same stalklike outgrowths of the stroma numerous tiny, cylindrical, colorless, continuous, sporelike bodies—so-called spermatia. These were produced either in separate pycnidia or spermagonia buried in the stroma or were present in great numbers in the same pycnidia as the large ovate spores. They were cut off from long slender basidia arranged radially, and measured 4 to 8 μ in length and 1 μ or less in diameter. The interior of the spermagonium was sometimes convoluted so that there were several centers of radiation. The germination of these small sporelike bodies has not been observed.

In 1,000-c.-c. corn-meal flasks inoculated from these 100-c.-c. flask cultures containing spores, the pycnidia developed much more rapidly, i. e., within seven weeks. The little tufts of hyphæ were observed in six days and in eight days looked like little woolly balls and were 1 to 2 mm. in diameter. They grew very rapidly, sometimes doubling in size in 24 hours. Sections of these made the eighteenth, twenty-third, and twenty-ninth days revealed the presence of immature pycnidia, but no spores were found until the forty-eighth day, at which time they were present in abundance. A very few of them were two-celled and occasionally one was germinating. Two days later the spores were being discharged in cirri. In some of the cirri the majority of the spores were two to three celled and were germinating; in others few, if any, had put forth a germ tube, and a septate spore was rarely observed. . Plates were poured from the pycnidia, and potato cylinders were inoculated with single spores germinating on these plates. It was one of these potato cultures, originating from a single spore, which was used for the orange-strain inoculations of July 21, 1909 (see p. 54). In the potato cultures mature pycnidia were found in four days, and in a liter corn-meal flask inoculated from the potato culture used for inoculation on July 21, 1909, pycnidia were present and discharging spores within seven days. Thus a vigorously fruiting strain has developed from the orange-knot strain. The pycnidia on corn meal are merely chambers in the stroma and have no distinct pycnidial wall. They are supplied with an ostiole and usually have a short neck which protrudes slightly above the surface of the substratum. The stalklike projections of the stroma were observed only in the small flasks (100-c.-c.) in which there was less moisture and the development was slower. In the liter flasks the pycnidia were produced in any portion of the thin, wrinkled stroma or in cushionlike elevations of it first noticeable as little tufts of hyphæ. The pycnidia were visible to the naked eye as tiny raised points thickly dotting the surface, although they were sometimes more or less concealed by the velvety gray surface growth of aerial hyphæ.

Prune agar.—On this medium there is good, but by no means copious, growth. The fungus covers the surface of the slant or plate with a thin layer composed for the most part of horizontal hyphæ. At the advancing edge there occurs in a few days a more dense growth consisting of short, branching, erect hyphæ, frequently in little tufts. In plate colonies that have attained the size of the plate, these hyphæ often form a marginal ring 0.5 to 1.5 cm. in width. They may also be scattered sparingly over the entire surface but are not easily observed with the naked eye.

Plates 9 cm. in diameter containing a single colony (inoculated in the center with a bit of mycelium) were covered by the fungus in 14 to 18 days (temperature 20° to 25° C.). The average growth per 24 hours for the first seven days was seven-eighths of a centimeter and was at a comparatively uniform rate for each colony. The most rapidly growing colony averaged 1 cm., and the one making the least growth 0.75 cm. per 24 hours. Colonies concentrically ringed. (Pl. IX, fig. 3.)

The pure white of very young cultures changes in a few days to grayish white and finally to black, with the exception of the aerial hyphæ, which usually remain grayish white. The dark color has a tendency to appear in concentric rings. Microscopical examination reveals the presence among the horizontal hyphæ of filaments of all gradations of color from hyalin to dark brown, often including some with a decidedly olivaceous tinge, but the macroscopical appearance of an old culture as a whole is black, although in plate cultures the olivaceous tinge is noticeable to the naked eye.

The hyphæ vary greatly in size, amount of branching, frequency of septa, and in general form. In some instances the septa are very infrequent, in others the cells are nearly isodiametric. A large proportion of the branches come off at right angles to the main filament, but they may be at any angle. The cell walls may be straight or undulating, and frequently the hyphæ are twisted imperfectly into loose or closer spirals. These undulating and spirally twisted hyphæ are often very noticeable in old cultures (three to four weeks), although they have been observed in cultures 2 days old. The hyphæ are often very much distorted and chlamydosporelike swellings are of very common occurrence, especially in filaments growing in the agar. The latter may occur in cultures of any age. Swollen hyalin cells may occur in brown hyphæ and vice versa. Sometimes these swollen cells are densely filled with protoplasm, but they do not possess a wall thicker than that of the rest of the filament and in all probability do not function as true chlamydospores.

Early in the growth of a prune-agar culture, sometimes in two days, interwoven hyphæ may be observed. Primary or secondary branches from the same or a neighboring hypha twine about the main filament. On slant agar these little tangles of hyphæ increase rapidly in size until (if they have turned dark in color in the meantime) they are visible to the naked eye as distinct, opaque, black bodies resembling pycnidia. Such bodies have been observed in prune-agar slants 5 days old. These masses of hyphæ may be elongated or irregular in shape but are most commonly approximately round.

Measurements taken from these bodies in a slant 13 days old varied from 40 to 136 μ. In plates the growth of these masses is much less rapid and in plate cultures 4 weeks old the individual hyphæ composing them could easily be distinguished. In a slant 8 months old a cellular tissue had formed very similar to the peridium of a pycnidium or perithecium, but in no case have these bodies been found to contain spores.[1]

The mycelium grows down into the agar but forms no stromatic layer on this medium. In old cultures the agar is so densely invaded by the black hyphæ that the whole is converted into a black mass.

Beef agar.—On nutrient peptonized beef agar +15, there is fairly good, though somewhat restricted, growth. Colonies attain the average size of 7 cm. in three to four weeks,[2] while on slant agar the growth is very compact and spreads slowly. On plates there is never a sufficient massing of the hyphæ to render the colony black as a whole, the color never being darker than a deep brown in the darkest portions. Colonies four weeks old were light brown, the darker portions corresponding with more or less uniformity to the concentric rings. There are a few, short (1 to 2 mm.), erect, grayish white, somewhat matted, aerial hyphæ, more abundant near the center of the colony.

Unlike their behavior on prune agar, on tubes of slant beef agar the hyphæ penetrate the substratum little, if any, but form on the surface of the medium a tough, black stromatic layer covered with short, grayish white hyphæ, erect at first, but becoming more or less matted. This layer is formed in about a week and may become one-half of a millimeter in thickness, but extends over only about one-third of the slant, which may or may not be covered by a thin layer of mycelium. In old cultures (4 weeks) the cells of the hyphæ composing the stroma are much swollen and distorted.

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[1] The fruiting orange strains have never been grown on this medium.

[2] On plates containing a single colony.

As on prune agar, the hyphæ vary widely in size, color, and frequency of septa. Coiling filaments, filaments with undulating walls, and fusion of hyphæ are frequent and sometimes in old cultures (4 weeks) the ends of the hyphæ are much swollen.

A striking characteristic of the mycelium grown on this medium is the occurrence, with more or less frequency, of thickenings on the outside of the walls, giving a warty appearance to the filament. These warty hyphæ have been observed in young and old cultures, on plates and slants, and in aerial and stromatic hyphæ. (Pl. IX, fig. 5.)

Interwoven hyalin hyphæ are of frequent occurrence in young cultures, but they increase very little in size and do not develop into black pycnidialike bodies visible to the naked eye, as do the similar knots of hyphæ on prune agar. (See p. 22.) None have been observed too dense to distinguish the individual filaments. (Pl. IX, fig. 6.)

A striking characteristic of the colonies on beef-agar plates was the occurrence of chains of swollen, colorless, chlamydosporelike cells (Pl. IX, fig. 1), particularly abundant near the margin of the colony. The majority of these were thick walled and resembled true chlamydospores. No brown ones were observed except in brown hyphæ. Swollen cells, sometimes full of protoplasm, sometimes nearly empty, are commonly present in all stages in old and young cultures both on slant agar and in plates, but those described resemble true chlamydospores much more closely than any others observed on this medium or on prune agar.

Potato agar.—Potato agar affords a most excellent medium for the lime-knot fungus. In one set of seven slant cultures two days after inoculation there was a luxuriant fluffy white growth of erect hyphæ about 2 mm. long, covering an area about 1½ cm. in diameter. Twenty-four hours later the growth had doubled, the erect hyphæ measured 3 to 5 mm., and there was a thin, barely visible layer of horizontal hyphæ extending beyond the mass of erect filaments. In four days the mycelial growth still presented a downy appearance, but was becoming somewhat matted. Five days after inoculation the growth next to the agar in the lower part of the slant was black and had formed a compact, tough stromatic layer. In some tubes this layer was covered with a thick, more or less matted coating of white or grayish white aerial hyphæ, while in others the latter had become a part of the black, compact, stromalike mass, which had a finely roughened surface and contained a few tiny, round, dense masses (visible by transmitted light) resembling the pycnidialike bodies on prune agar. No pycnidia were ever found. The fruiting strains discovered after this work was done have not been grown on slant potato agar.

Sometimes the cultures undergo the changes noted less rapidly, e. g., in two other sets of cultures there was still a thick, fluffy, white, surface growth of erect hyphæ after 10 days, with only a tinge of gray in some of the older hyphæ. Growth sometimes colony-wise.

Growth of the lime-knot strain on +6, +8, and neutral potato agar, Fuller's scale (Pl. VII, fig. 4), varied little, if any, but the orange strain isolated from knots on orange made a much better growth on the +8 agar than on the neutral agar (Pl. VII, fig. 5) and also grew more rapidly on the former than the lime-knot strain.[1] There was no penetration of the agar by the hyphæ, nor was the agar stained.

Colonies on potato-agar plates attained a diameter of 1.5 to 2 cm. in 48 hours.[2] Growth quite dense, but composed of horizontal hyphæ with the exception of a marginal ring of erect hyphæ about 1 mm. long. In two weeks the colonies were 7 to 8 cm. in diameter and still white with the exception of a black ring near the margin. The dark color was first noticeable in 11 or 12 days.

In very young slant cultures many of the hyphæ are rather coarse (4 to 8 μ), have a very few septa, often have undulating walls, and frequently are coiled into rings or spirals. There are also many very fine filaments not exceeding 1 μ in width. A few days later many of the filaments are considerably distorted and the septa are more frequent.

In very old cultures (8 months) coarse, many-septate filaments (Pl. VIII, fig. 10) and very much distorted hyphæ (both hyalin and colored) are very common. Some of the colored filaments are divided into approximately isodiametric cells with slightly bulging lateral walls. Fused and warty, colored hyphæ are also of common occurrence. (Pl. VIII, figs. 7 and 8.) The color is in the cell wall; hence the warts, being much thicker and therefore blacker than the rest of the wall, give to the hyphæ a mottled appearance.

In young colonies on plates the hyphæ are curling and often so thickly beset with short branches that they have almost a spiny appearance.

In plates poured from spores from the fruiting orange-knot strain, the spores germinated (Pl. VIII, fig. 4) and in many cases produced very long, much-branched hyphæ in less than 24 hours. In five days mature pycnidia were present in abundance. They formed most thickly on the margins of the colonies and made a solid marginal ring. (Pl. IX, fig. 2.) No spermatia were found when the plates were 3 weeks old, but later (41 days) they were present in abundance. At this date some of the large ovoid spores were one to two.septate.

Corn-meal agar.—Very poor growth on this medium. Surface of the slant barely covered in a week with a thin, almost invisible mycelial layer of horizontal hyphæ. In two cultures 5 weeks old one contained sufficient colored hyphæ to give a decidedly greenish black tinge to the lower half of the slant, while in the second tube barely a trace of color was visible. No interwoven hyphæ were observed and few chlamydosporelike swellings. There was no stromatic layer.

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[1] The more rapid growth of the orange strain was probably due to its more recent isolation.

[2] Each plate contained a single colony.

Colonies in plates of this medium were 6 to 7 cm. in diameter (5 weeks) and had made no growth after the third week.[1] A few aerial hyphæ were in the central portion. About one-half to two-thirds of the hyphæ (5-weeks-old colonies) were colored, practically all the color having appeared after the colonies ceased to increase in size.

Hyphæ rather straight for the most part and very much less distorted than on prune or beef agar. Filaments in plate 5 weeks old measured 2 to 4 μ in diameter. Found a very few of the warty hyphæ described under growth on beef agar.

Silica jelly.[2]—Poor growth. In five days the mycelium covered an area 6 to 8 mm. in diameter. Hyphæ short, rising above the surface scarcely 1 mm., but penetrating the substratum to a depth of 2 to 3 mm. In eight days the area of growth was about 12 to 20 mm. in diameter. Color, dark gray. In 16 days there had been only a very slight increase in growth. The margin of the colony was white or nearly so, while the central portion was nearly black.

In cultures 5 years old there was a tough black stroma about 0.5 mm. thick, covered by a thin brownish gray mycelial layer. No chlamydospores or pycnidia were found.

Nutrient gelatin slants.—There is slow liquefaction of gelatin by both the lime and orange strains (fruiting and nonfruiting), the slowness being due in part, no doubt, to the temperature of the ice thermostat in which the cultures were kept. The temperature ranged from 15.5° to 20° C. and averaged 17.5° C., which is far below the optimum for this fungus (see p. 36). Within 24 hours 11 out of 22 cultures showed a sunken area beneath the inoculating material, varying from a slight depression to a pit 2 or 3 mm. deep. There were no signs of growth in any of the cultures. After six days there were still two tubes that showed no signs of liquefaction. In 10 days, however, there was at least a small pit in all the cultures. On the sixteenth day the amount of liquefaction varied from a small pit about 1 mm. deep (lime strain) to about three-fourths of the gelatin (fruiting orange strain). Most of the tubes contained deep pits and considerable liquid gelatin. The fruiting orange strain had led in the amount of liquefaction from the beginning. With the exception of a few tubes the growth on the sixteenth day was restricted to a new outgrowth of short hyphæ on the bit of stroma used for inoculation. In the fruiting orange strain, however, the liquid gelatin was nearly full of fluffy white mycelium and in one of these tubes, on the surface of the slant above the liquid, there was an area of dark-gray growth (0.5 by 1 cm.) of creeping hyphæ on which little cushionlike elevations were forming. In one of the cultures of the nonfruiting orange strain the deep pit which had formed was lined with a good white growth of creeping hyphæ covering an area about 2 by 2.5 cm. in extent.

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[1] Each plate contained a single colony.

[2] Slant cultures.

In 19 days one of the fruiting orange strain cultures had formed a partial dark-gray pellicle composed of hyphæ full of chlamydospore-like swellings.

All of the gelatin in all of the tubes liquefied in 38 days.

Steamed potato cylinders.—Excellent growth. The third day (65 hours) there was a thin white mycelial layer covering about one-third the surface of the potato above the water.[1] Twenty-four hours later the whole of the potato above the water was covered with a thick downy white growth of feathery hyphæ 4 to 10 mm. long (24.5° C.). The sixth day the mass of erect hyphæ was decidedly gray, with the exception of the youngest filaments, and was becoming somewhat matted, while next to the surface of the potato a black stroma about one-third of a millimeter thick had formed at the base of the slant next to the walls of the tube. Microscopical examination showed the presence of many swollen cells in the hyphæ both in the stroma and in the surface growth. Individual filaments olivaceous or hyalin, gray or black (in stroma) in mass. Great variation in size of hyphæ. Some coarse brown filaments with nearly isodiametric cells among the erect hyphæ.

When the cultures were 3 weeks old the potato cylinders were practically covered with a thick, wrinkled, black stroma coated by a thin, matted layer of grayish white hyphæ. Two weeks later portions of this external layer were nearly black, while others, a more recent growth, were white (Pl. VII, fig. 2). Small portions of the stroma were white and others were cream buff (Ridgway's Nomenclature of Colors). In one set of cultures, 4 weeks old, of the lime-knot strain, there were cushionlike elevations of the stroma 2 to 5 mm. in diameter. These were full of pycnidialike chambers, but no spores were present. No spores have been found upon potato except in cultures made from the fruiting orange strain.

Potato cultures 3 weeks old were tested with potassium iodid for starch. A microscopical examination was made of the tissues so treated. Aside from a very faint purplish stain in a few cells there was no reaction in any portion of the potato which was covered by the stroma. The tissue of the potato was penetrated by hyalin hyphæ and was much softened. The hyphæ in the tissue were much distorted and full of chlamydosporelike swellings (Pl. IX, fig. 4).

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[1] Growth is sometimes much more rapid than this (Pl. VII, fig. 3).

Orange strain on potato cylinders.—The second isolation of the orange strain (isolated July 22, 1909, from a Jamaican knot received in January) behaved on potato in the same manner as the lime strain, making an excellent growth and producing a thick, tough stroma. No spores have been found in the cultures, although this strain has produced pycnidia on the host. (See orange-strain inoculations of July 29, 1909, p. 58.)

The fruiting orange strain, however (see orange strain on corn meal, p. 20), in all cultures that were fruiting abundantly produced instead of a thick, tough stroma a thin, crustlike layer consisting mostly of pycnidia.[1] The pycnidia appeared in great numbers in three or four days, closely crowded together, and were almost concealed at first by the surface hyphæ. In five or six days little round white masses of discharged spores dotted the surface of the culture. Some of the spores in cultures eight days old were pale yellowish, but by far the majority were colorless. In cultures 39 days old spermatia were present in abundance. These were not observed when the cultures were 20 days old.

Sometimes there is little more than the pycnidium wall separating the pycnidia. Sometimes the pycnidium is surrounded by a well-defined subiculum. The fungous layer is thin and easily broken or crushed, in marked contrast to the thick, tough stromatic layer in cultures of the lime strain and the nonfruiting orange strain. The surface of the mycelial layer is thickly dotted with the necks of the pycnidia which protrude slightly above it. Some of the pycnidia have necks nearly as long as the body of the receptacle and are truly flask shaped, while others are nearly spherical and still others spheroidal. These all usually taper, at least slightly, toward the ostiole through which the spores are discharged. Occasionally the wall is so thin that it is transparent and the spores are visible within. In old cultures (41 days) there were many one to two septate spores, although the majority were continuous. One with four septa was observed. Many of the brown septate bodies (see p. 16) were present also (Pl. VIII, fig. 5).

Steamed banana cylinders.—Moderate amount of growth in seven days as a thin, delicate, white layer, covering the slanted portion of the cylinders. Banana plainly visible through the fungous growth. Compact matlike growth covering the fluid.

In cultures 5 years old large, brown, thick-walled chlamydospores were present in abundance. These were one to several celled with walls in various planes and were often very irregular in shape (fig. 6). There were also some thick-walled colorless chlamydospores. Stromalike layer about 1 mm. thick covered by a feltlike layer varying in color from light brown or grayish white to black. No pycnidia found.

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[1] If the cultures were fruiting less abundantly the thick, tough stroma was produced, and in this were embedded the pycnidial chambers.

Steamed apple cylinders.—Good growth. In cultures 8 days old the cylinders were entirely or partially covered with a rather thin dark-brown, nearly black, mycelial layer. The erect hyphæ extended 4 to 6 mm. above the substratum. There was a decided browning (tawny, Ridgway's Nomenclature of Colors) of the apple which extended beyond the fungous growth. The apple in the check tube was approximately Ridgway's cream buff.

In cultures 9 months old the mycelial layer was about 2 mm. thick, dark brown, and feltlike, and there were small tufts of hyphæ about 2 mm. in diameter in the center of which a small amount of pseudoparenchyma had formed. Microscopical examination was made of cultures at this age. The hyphæ were very dark brown and comparatively straight for the most part, although in some instances the walls were undulating. Filaments varied from 2 to 8 μ in width, the majority being about 3 μ wide. Septa frequent. Warty hyphæ present. No swellings observed in the filaments.

Cultures 18 months old and also 5-year-old cultures contained large, brown, one to several celled chlamydospores, resembling those on old banana cultures. Many warty hyphæ and hyphæ divided into approximately isodiametric cells were present in these old cultures. No pycnidia were found.

Steamed carrot cylinders.—Steamed carrot is an excellent medium for this fungus. Abundant white growth in four days. Hyphæ rising several millimeters above the substratum giving a woolly appearance to the cultures. In eight days the growth was light gray and tufted. Sixteen days after inoculation the mycelium had become a darker gray and was matted into a feltlike layer in places. No change in the color of the medium.

In cultures 5 years old a few pycnidia were found. There was a rather thin tough stroma covered by a dark-brown, feltlike matted layer of aerial hyphæ. There were a very few large, brown, one to several celled chlamydospores like those described in old banana cultures. In some of the cultures long chains of chlamydosporelike swellings were found in abundance (fig. 7). Some of these were brown and some were colorless, with coarsely granular contents. Usually only cross walls occurred, but occasionally a longitudinal septum was found. Walls thin. Warty hyphæ present. Warts very large, as on lime-wood cylinders. (See p. 31.)

Steamed macaroni cylinders.—Good, though rather slow, growth. In four days there was very slight, barely visible growth, hyphæ rising very little from the substratum. In 12 days all of the macaroni above the water was covered by a thin, dark-gray, feltlike mycelial layer. In four weeks the fungous layer had become 1.5 to 3.5 mm. thick, and varied in color from grayish to nearly black. The filaments varied in diameter from 3.5 to 7.5 μ, the finer hyphæ being the more common.

In cultures 5 years old the substratum was covered by a thin, tough, black stroma with a thin, dark-brown, feltlike superficial layer of hyphæ. No pycnidia or chlamydospores were found.

Steamed orange rind.—In seven days the fungus had covered the greater part of the surface with a thin layer of mycelium, white for the most part but turning dark in portions. In some of the tubes tiny spherical bodies resembling those described on lime-wood cylinders (see p. 31) were present when the cultures were 10 weeks old.

A very few pycnidia from which the large, hyalin, one-celled spores had been discharged in cirri were found in a culture 17½ months old and also in one 5 years old. No chlamydospores observed. Mycelium grayish to dark brown. Thin, black stroma.

Steamed parsnip cylinders.—Copious light-gray growth in eight days, covering all portions of the cylinder above water. Erect hyphæ 4 to 8 mm. long. Small spherical masses of pseudotissue like those described on lime-wood cylinders (see p. 31) in some of the tubes.

A few pycnidia with large, hyalin, one-celled spores discharged in cirri were found in two cultures 5 years old. These cultures also contained a few brown chlamydospores, chains of swollen colorless cells, and a thin, tough, black stroma with a feltlike coating of dark-brown hyphæ.

Steamed prunes.—Slight growth in two days, erect hyphæ rising 1 to 2 mm. above the substratum. In seven days there was a thin cobweblike growth of long, branching, colorless hyphæ, 4 to 5 mm. long. Many of these were very coarse (12 μ in diameter) and were breaking up into one to several celled portions, some of which were germinating. Most of the cells in these portions were approximately isodiametric. There was no bulging of the lateral walls. Sometimes the end walls were rounded, but often they were not.

In cultures 5 years old there was a fairly good growth of brownish gray mycelium. No pycnidia or stroma had formed. Many germinated fragments of colorless hyphæ were present, some with thick walls and some with thin. There also were colored hyphæ breaking up in the same manner, but none were observed which had germinated. Large, brown, thick-walled chlamydospores were present, resembling those in old banana cultures, but smaller for the most part and containing fewer cells.

Cultures of the fruiting orange strain produced a more compact growth of short colorless hyphæ and in seven days were fruiting abundantly. A few septate spores. No long cobwebby hyphæ. No stroma.

In cultures of the nonfruiting orange strain there were in seven days little tufts of short grayish hyphæ dotting the surface of the medium. The interior of these was composed of brown hyphæ but no pseudotissue had formed. In both this and the fruiting orange strain some of the hyphæ had broken into short fragments, but to a very much less degree than in the lime strain.

Steamed salsify cylinders.—Good growth on this medium. In cultures 8 days old the portion of the cylinder above the water was covered with a thick feltlike layer of light-gray mycelium. In cultures 5 years old there was a thin, black stromatic layer covered with grayish brown hyphæ. Neither pycnospores nor chlamydospores were observed.

Steamed sweet potato cylinders.—Good growth. In seven days all of the cylinder above the water was covered with a thick gray feltlike layer. In cultures 9 months old the mycelium was very dark brown, almost black. Many of the hyphæ were divided into approximately isodiametric cells with bulging lateral walls. In one of a set of five cultures 5 years old, both pycnospores and spermatia were found. The pycnospores measured 16 to 32 μ by 4 to 6 μ. The spermatia were slightly larger on this medium than on corn meal. They measured 4 to 10 μ by 1 to 1.5 μ, the majority being 4 to 6 μ. Good, tough, black stroma.

Steamed tomato.—Moderate growth in four days, covering the greater portion of the surface of the medium and forming tufts of hyphæ. Mycelium grayish white. Four days later the color was dark gray. In cultures 5 years old there were chains of brown and colorless chlamydospores resembling those on carrot cylinders. No pycnospores found. Thin stromalike layer formed on this medium.

Steamed turnip cylinders.—Rather scanty growth in four days. In eight days there was a good gray growth covering the portions of the cylinder above the water and small round masses of pseudotissue had formed. The mycelium in old cultures (9 months) was very dark brown, nearly black. In cultures 5 years old a few cirri of discharged pycnospores were found in each of the six tubes. The cirri in these very old cultures were yellowish. Spores one celled with few exceptions. There were a few warty hyphæ and a very few brown chlamydospores. Thin, tough, black stroma.

Steamed lime-wood cylinders.—Some of the tubes contained twice-distilled water, others peptone water, but there was no noticeable difference in the amount of growth made by the fungus on the two media. The cylinders were inoculated with mycelium from cultures 2 weeks old, and in less than 20 hours the growth was sufficient to be seen easily with the naked eye. The hyphæ in some of the tubes were about 1.5 cm. long. In three days most of the cylinder above the water was covered with white hyphæ. The majority of the filaments were creeping, but there was a fairly good, though rather thin, woolly growth of aerial hyphæ.

In five days practically the whole cylinder was covered; mycelium still white. When the cultures were 2 weeks old the hyphæ were more or less matted and were very dark brown for the most part. The wood was colored also (it was found later that the hyphæ had penetrated the cylinders).

Six weeks after inoculation many little spherical, gray bodies were present in the cultures. One of the tubes, with twice-distilled water, contained several hundred of these. (Pl. VII, fig. 1.) They averaged 2 to 3 mm. in diameter and were very hard and attached very firmly to the substratum. Microscopical examination showed them to be composed of a compact mass of pseudoparenchyma, with a covering of short grayish hyphæ. Microtome sections were made of some of these bodies from cultures 2 months old (fig. 8). Some cultures on this medium were kept for five years, but no pycnidia or perithecia ever developed. The mycelium in these old cultures varied in color from a pale brownish gray to a very dark brown and formed a feltlike layer covering the cylinders. No stromatic layer. The hyphæ were much septate and sometimes warty. The warts were much larger than any observed in beef agar, frequently being 2 to 4 μ thick. In the tubes with peptone water there were varying numbers of chlamydospores. Most of the tubes contained very few, but in one culture there were chains of them, both brown and colorless, most of them one celled. The colorless ones had coarsely granular contents. None were observed in the tubes containing distilled water.

The cylinders were penetrated to a greater or less degree by the hyphæ. In one tube to which sterile water had been added one and two months after inoculation, the hyphæ had penetrated the whole length of the cylinder (5.5 cm.), and the wood and pith were plentifully streaked with black.

Steamed lemon twigs.—In three days the portion of the twig above the water was practically covered with a white cobwebby growth. In seven days the mycelium was turning gray and had formed a feltlike layer. Numerous tiny white tufts or cushionlike masses.

In cultures 5 years old the wood was covered with a thin feltlike layer of mycelium varying in color from light brown to dark brown. Cushionlike masses of pseudoparenchyma. No pycnidia or chlamydospores observed.

Beef bouillon.—Good, though rather slow, growth in beef bouillon +15 (Fuller's scale). In six days there was an excellent, fluffy, woolly, white growth of hyphæ about 1.5 cm. long. In nine days one of the three tubes had a white pellicle, which 24 hours later had a very faint gray tinge. When the cultures were 4 weeks old, one had a tough black pellicle, another a gray, and the third a white one. In all three the growth in the fluid was pure white and contained many crystals.

In 6-day-old cultures the mycelium was rather fine (the majority of the hyphæ measured 2 to 3 μ), branching, and with few septa. In the cultures 2 months old the septa were much more frequent, the walls were more or less irregular in outline, and there were many incipient branches. The hyphæ in the compact, tough mat forming the pellicle were full of large swellings.

Raulin's fluid.—Good growth in this medium. In five days there was a tuft of very white fluffy mycelium about three-fourths of a centimeter in diameter in the bottom of the tube. The growth gradually increased, until at the end of six weeks the fungus filled the liquid and had formed a dark-gray pellicle on the surface. The submerged mycelium was still pure white.

In cultures 5 years old the dark-brown pellicle or stroma had cushionlike elevations 2 to 3 mm. in diameter. Some of these contained pycnidia which were mere cavities in the stroma and from which the spores were discharged in cirri. The spores measured 20 to 32 μ by 4 to 8 μ. Some were quite broad and short (20 by 8 μ), some were long and slender (32 by 4 μ), but 32 by 8 μ was the average size for the majority.

There were a few spermatia and brown chlamydospores present also. The majority of the spermatia were 4 to 5 μ long.

Fraenkel and Voge's solution.—There is very poor growth in this medium. Eight days after inoculation the growth consisted of a tuft of grayish mycelium about 0.5 cm. in diameter. When the cultures were 2 weeks old, the tufts had not increased noticeably in size, but they were nearly black. The hyphæ were short, forming a compact mass. The cultures were under observation for six weeks, but there was little if any further growth.

Milk.—No change occurred in the appearance of the milk until the fourth day. On that day 8 out of 14 cultures had a translucent band 2 to 10 mm. wide from which the casein was being precipitated. Among these eight tubes were cultures from three strains—the lime and the fruiting and nonfruiting orange strains. The milk below this translucent band was still fluid and opaque, but in some of the tubes it was of a thick creamy consistency. In nearly all of the cultures there was a good, firm, white or gray pellicle. The fifth day soft creamy clots were forming around the submerged hyphæ. The seventh day the band of translucent whey, which was slowly becoming more transparent, was 1 to 2.5 cm. wide in most of the cultures, although in a few tubes precipitation was going on much more slowly.

Two cultures of the nonfruiting orange strain had quite solid clots of casein in the bottom. The cultures of this strain had undergone the changes described more rapidly from the beginning than those of the other two strains. Pycnidia present on the seventh day in the rim and pellicle of the fruiting orange strain. On the eleventh day several of the cultures contained solid clots of casein, filling one-fourth to one-third of the liquid. The whey above this was transparent or semitransparent. In other tubes the casein was being precipitated more slowly and had not made solid clots. In two of the lime-strain cultures the milk was translucent throughout, with the exception of a very small clot in the bottom. In one of the lime-strain cultures the milk above the solid clot, which filled about one-fourth of the liquid, was opaque and between Ridgway's smoke gray and olive gray. Seven days later (cultures 18 days old) the small amount of curd in two of the lime-strain cultures had been dissolved and the fluid was translucent throughout. In the other tubes (all strains) there was still a soft curd, above which the fluid was clear or translucent.

In a later experiment in which the cultures were under observation for four weeks the fluid was clear and there was no curd at the end of that period. There had been a soft curd earlier in the life of the cultures, but this had been completely dissolved.

Litmus milk.—When cultures (both lime and orange strains) were made in milk to which sufficient litmus had been added to make it lilac color the translucent portion (see milk cultures, p. 32) became purplish. On the sixth day the color varied in the different cultures from plum purple to Indian purple (Ridgway), while the color of the milk below the translucent band was unchanged. Where there was cream in the rim it was colored rose pink (Ridgway) on this date. This color disappeared later, however. The change in color followed the increase of the translucent or transparent zone, and by the tenth day nearly all of the cultures were prune purple or Indian purple throughout. There had been no indication of any more decided acid production at any time. On the seventeenth day the cultures of the lime strain were all approximately Ridgway's prune purple. Those of the nonfruiting orange strain varied from pansy purple to prune purple and a very deep purple that was nearly black, and the cultures of the fruiting orange strain were prune purple and pansy purple. In one of the cultures of the fruiting strain the lower half of the milk was pansy purple, while the upper half was nearly colorless (slightly brownish yellow) and perfectly transparent except for a few small granules, probably portions of the clot not yet dissolved. All of the cultures in all of the strains were transparent and none contained clots. These cultures were under observation for 35 days. At the end of that time the fruiting orange strain[1] showed complete reduction in one tube and partial reduction in the remaining four tubes. No reduction in the nonfruiting orange or lime strains. Similar results were obtained in another set of experiments in which two tubes of the fruiting orange strain[1] showed partial reduction in 20 days and complete reduction in 38 days,[2] while even at the end of 44 days there was none in the nonfruiting orange or lime strains.

In another experiment, however, one of the nonfruiting orange cultures showed almost complete reduction in 30 days, while no signs of it were exhibited by the other strains. It is probable that all the strains are capable of reducing litmus if sufficient time is devoted to the experiment.

Association experiment on prune agar (lime strain plus orange strain).—Prune-agar plates were inoculated on opposite sides with mycelium from corn-meal flask cultures of the lime and orange strain (nonfruiting). No fruiting bodies of any kind appeared but the difference in the amount of growth was most striking. On the twenty-first day the orange strain had made nearly three times as much growth as the lime. Neither strain made any further growth.

CULTURE MEDIA.

The culture media used in these experiments were prepared as follows:

Fruit and vegetable cylinders.—The fruits or vegetables were thoroughly scrubbed with a brush, pared (except prunes and oranges), and washed in distilled water. Cylinders were then cut and put into test tubes with sufficient twice-distilled water to cover them about half way. Tubes either autoclaved for 15 minutes at 110° C. or steamed for 15 to 20 minutes on three consecutive days.

Lime and lemon wood cylinders.—Small branches of lime and lemon trees were cut into sections about 2 inches long and put into test tubes (one in each tube), with 10 to 15 c. c. of distilled water. Tubes then autoclaved for 10 minutes at 120° C.

Macaroni.—Prepared like wood cylinders.

Corn meal.—Corn meal with sufficient twice-distilled water to cover it thoroughly was put into flasks (about three heaping teaspoonfuls of corn meal to a 100-c.-c. flask). Autoclaved 30 minutes at 115° C.

Potato agar.—Selected smooth, firm potatoes, washed and scrubbed thoroughly with a brush, pared, and cut into thin slices or shredded, added two parts twice-distilled water, let simmer for half an hour, strained off water, filtered through paper or gauze, and to the filtrate added 1 per cent of agar flour. Steamed 45 minutes, filtered, and tubed. Tubes autoclaved 15 minutes at 110° C.

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[1] One transfer removed from germinating spores in an agar plate.

[2] Seven separate colonies of the fruiting orange strain are represented by these two experiments.

Prune agar.—Five dry prunes washed thoroughly under the tap, put into a beaker containing 1 liter of distilled water and allowed to simmer for one hour, then brought to a boil for five minutes. Filtered off juice through filter paper and added 1.5 or 2 per cent of agar flour. Steamed three-quarters of an hour, filtered, and tubed. Titrated usually about +6 Fuller's scale. Tubes autoclaved 15 minutes at 110° C. or steamed for 15 minutes on three consecutive days.

Apple agar.—Pared and cut apples into thin slices, added two parts of distilled water. Boiled 20 minutes, strained through gauze and added 1 per cent of agar flour. Steamed one-half hour. Filtered and tubed. Autoclaved 15 minutes at 115° C.

Apple-twig agar.—To 500 grams of apple twigs cut into small pieces, added 1,000 c. c. of distilled water. Boiled 20 minutes. Strained through gauze and added 1 per cent of agar flour. Steamed one-half hour, filtered, and tubed. Autoclaved 15 minutes at 115° C.

Corn-meal agar.—To 3 liters of distilled water added 12 teaspoonfuls corn meal. Kept in water bath, temperature about 58° C. Strained through gauze, steamed one hour, filtered through paper. Added 1 per cent of agar flour. Steamed one hour, filtered through paper, tubed. Autoclaved for 15 minutes at 115° C.

Beef agar.—To 1,000 cubic centimeters of peptonized beef bouillon added 1 per cent of agar flour. Steamed three-quarters of an hour. cooled down to below 60° C., and added the neutralized whites of two eggs to clarify. Steamed three-quarters of an hour, filtered, and tubed. Made +15 Fuller's scale by adding $4\frac{NaOH}{1}$. Tubes autoclaved 15 minutes at 110° C.

Silica jelly.—100 c. c. sodium silicate, sp. gr. 1.15° Beaumé, 100 c. c. HCl 1.10° Beaumé.

Dialized 24 hours in tap water in collodion sacks. Boiled, filtered hot, and cooled in ice water.

To 85 c. c. of above was added 15 c. c. of Fermi's solution. Tubed and autoclaved 15 minutes at 110° C., with vent shut down as soon as steam came out, and kept closed.

Peptonized beef bouillon.—Prepared in the manner described in "Bacteria in Relation to Plant Diseases," by Erwin F. Smith (vol. 1, p. 195) and made +15 Fuller's scale.

Fermi's solution.—

Distilled water	1,000.0 c. c.
Magnesium sulphate	.2 gram.
Acid potassium phosphate	1.0 gram.
Ammonium phosphate	10.0 grams.
Glycerin	45.0 c. c.

Fraenkel and Voge's solution.—To 500 c. c. of redistilled water were added the following:

Sodium chlorid	2.5 grams.
Dipotassium phosphate	1.0 gram.
Ammonium lactate	3.0 grams.
Sodium asparaginate	2.0 grams.

Steamed 20 minutes, filtered, tubed, and tubes steamed for 15 minutes on each of three consecutive days.

Raulin's fluid.—To 1,500 c. c. of redistilled water were added the following:

Cane sugar, granulated	70.00 grams.
Tartaric acid, crystals, Merck's	4.00 grams.
Ammonium nitrate C. P., Baker & Adamson	4.00 grams.
Ammonium phosphate, reagent, Merck's	60.00 grams.
Potassium carbonate, standard, E. & A	60.00 grams.
Magnesium carbonate C. P., Baker & Adamson	40.00 grams.
Ammonium sulphate C. P., E. & A	25.00 grams.
Zinc sulphate C. P., E. & A	.07 gram.
Ferrous sulphate, crystals, C. P., Merck's	.07 gram.
Potassium silicate, dry, E. & A	.07 gram.

Steamed 10 minutes at 100° C. Filtered and pipetted into test tubes. Tubes steamed for 15 minutes on each of three consecutive days.

TEMPERATURE RELATIONS.

Potato cultures of the lime strain of this fungus were placed in thermostats at different temperatures, two tubes placed at each temperature, as shown in Table I. Temperatures were recorded two to three times a day.

TABLE I.—*Thermostat and room temperatures in which potato cultures of lime strain of fungus were kept.*

Room or thermostat.	Temperatures (° C.).	
	Average.	Range of variation.
Ice thermostat 2	3.5	2.75 to 4.8
Ice thermostat 10	16.8	14 to 19
Room temperature	23.4	19 to 27
Thermostat 1	31.75	30 to 34.5
Thermostat 2	35.4	33 to 38.5
Thermostat 3	44	36 to 49
Thermostat 4	37.9	31 to 43

The cultures were under observation for five weeks (daily observation for 2 weeks), but no spores of any kind were formed. No growth took place at 3.5° C. or at 44°, and only scanty growth at 37.9°, while at 16.8°, 23.4°, 31.75°, and 35.4° C. the growth was excellent, though differing widely in rate, as shown in Table II.

TABLE II.—*Reaction of Sphaeropsis tumefaciens on potato to different temperatures.*

Time of observation.	Average temperature (° C.) and place where cultures were kept.				
	16.8° (ice thermostat 10).	23.4° (room).	31.75° (thermostat 1).	35.4° (thermostat 2).	37.9° (thermostat 4).
18 hours (1st day)	No growth; 14.5° C.	No growth; 22.5° C.	Growth about 5 mm. in diameter in one tube; 30.25° C.	Small amount of growth in one tube; 33.5° C.	Slight growth in one tube; 40° C.
24 hours (1st day)	No growth; 15.75° C.	No growth; 23° C.	Good growth in both tubes; long, erect hyphæ; 30.5° C.	Good growth in both tubes, somewhat less than in thermostat 1; 34° C.	Slight growth in one tube; 35° C.
41 hours (2d day)	No growth; 14.75° C.	No growth; 23° C.	Excellent white growth, nearly covering the surface of the potato above the water; long, white hyphæ; 30.5° C.	Nearly as good growth as in thermostat 1; hyphæ slightly shorter; 33.75° C.	Slightly more growth than yesterday; barely visible, however; 35.25° C.
47 hours (2d day)	No growth; 16.75° C.	No growth; 25.5° C.	Growing very rapidly; much more growth than 6 hours ago; feathery hyphæ 5 to 6 mm. long; 31° C.	Growing rapidly; long feathery hyphæ. Somewhat less growth than in thermostat 1; 34.75° C.	No change; 37° C.
65 hours (3d day)	No growth; 16° C.	Thin white growth covering about one-third the surface of the potato above the water; 24.5° C.	Growth extending down into the water now; slight tinge of gray in small area in one tube; 32.25° C.	No gray tinge; 36° C.	Slightly more growth; 41.75° C.
69 hours (3d day)	Very small amount of barely visible growth in tube 5; 16.25° C.	25° C.	32.5° C.	36° C.	No change; 39.5° C.
89 hours (4th day)	Scanty growth in tube 5, covering area about 1 cm. in diameter; small amount of mycelium growing on the walls of tube 6; 17.5° C.	Excellent growth in both tubes; surface of potato above water is covered with a thick downy white growth 4 to 6 mm. high; very great amount of growth in last 24 hours; 24.5° C.	Growth becoming more or less matted. Pale-yellow stromalike layer; 32.25° C.	Resembles growth in thermostat 1; stromalike layer is cream color; 36° C.	Scanty growth covering surface of potato in tube 14; no growth in tube 13; 31° C.
137 hours (6th day)	Half the surface of potato above water is covered with a thin growth of white mycelium in tube 5; tube 6, only half as much growth; 19° C.	Growth excellent and somewhat matted; more abundant growth (i. e., above water) than in thermostat 1; all but the youngest growth is decidedly gray; black stroma next to potato; 25° C.	Growth above water less copious than at room temperature and much less gray, but whole surface of potato, including portion in water, is covered; mycelium in water is white, with exception of yellowish stromalike portion; black stroma above water; 32.75° C.	Very much less growth than in thermostat 1 and at room temperature; surface of potato covered; mycelium white; growth more or less matted; cream color stroma; 36° C.	Very slight growth in tube 13; growth in tube 14 is still only barely visible; 48° C.

TABLE II.—*Reaction of Sphaeropsis tumefaciens on potato to different temperatures*—Continued.

Time of observation.	Average temperature (° C.) and place where cultures were kept.				
	16.8° (ice thermostat 10).	23.4° (room).	31.75° (thermostat 1).	35.4° (thermostat 2).	37.9° (thermostat 4).
161 hours (7th day)	Considerably more growth in tube 6, but very scanty in both tubes; 15.75° C.	No change, except that culture as a whole is becoming darker in color; 20.5° C.	Gray color has deepened very much in 24 hours and now extends to the greater part of the growth; much less color than in cultures at room temperature; 31.25° C.	Large gray area in both tubes; no traces of color 18 hours earlier; about as much color as in thermostat 1 cultures 18 hours ago; 34.9° C.	Slightly more growth; 32.5° C.
185 hours (8th day)	Slight increase in growth; 15.5° C.	Little, if any, change; 19° C.	Little, if any, change; 31.25° C.	Little, if any, change; 35° C.	Little, if any, change; 35° C.
214 hours (9th day)	No change; 17.8° C.	Growth extending into the water and becoming darker colored; 24° C.	No change; 31.25° C.	No change; 34.8° C.	Slightly more growth in tube 14; plainly visible now; 43° C.
233 hours (10th day)	Fungus growing very slowly, but amount of growth has doubled in last 48 hours; growth olivaceous in tube 5; 17.9° C.	Little, if any, change; 24° C.	Growth slightly darker in color; 32° C.	No change; 36° C.	No change; 37.5° C.
264 hours (13th day)	Excellent woolly white growth in tube 6; growth in tube 5 is black, but much less in amount; 19° C.	No change.	Growth becoming blacker in tube 8; 34.5° C.	Growth in tube 9 becoming darker; 38.25° C.	Good growth in upper half of cylinder in tube 14; hyphæ short; 40° C.
306 hours (15th day)	Black color appearing in tube 6; 16.8° C.	No change; 21° C.	No change; 34° C.	No change; 38.5° C.	No change; 40.5° C.
22d day	Excellent growth in both tubes, though less than at room temperature and in thermostats 1 and 2; grayish white surface growth with tough, black, wrinkled stroma underneath; 15° C.	Excellent growth; cylinders nearly covered with a tough, black, wrinkled stroma; surface hyphæ gray and matted; small portion of stroma is pale buff yellow as in thermostats 1 and 2; more growth than in any of the thermostats; 21° C.	Whole cylinder covered with a tough wrinkled stroma, black for the most part, but with pale yellow portions; 30° C.	Somewhat less growth than in thermostat 1; tough, wrinkled, black stroma, pale yellow in places; 36° C.	Upper third of cylinder in tube 14 is covered with a compact, feltlike yellowish white growth of short matted hyphæ, with a tough whitish stroma underneath; only a very small amount of growth in tube 13 and this has dried out completely; 39° C.
36 days	Cultures resemble those at room temperature very closely, except that coating of grayish white hyphæ over the black stroma is thicker; growth has been excellent, but slow.	Much of the matted layer of surface hyphæ coating the stroma is nearly black, but youngest portions are white; small portions of stroma are a pale yellow or cream buff (Ridgway).	No change.	No change.	No change.

On the thirty-sixth day all the cultures were removed to room temperature. Six days later tube 14 from thermostat 4 contained an excellent, gray-white, matted, surface growth with a tough, black, somewhat wrinkled stroma entirely covering the surface of the potato. None of the others had changed in appearance.

No fruiting bodies formed in any of the tubes. The only difference noted in the cultures at the different temperatures was in the rate of growth. On the twenty-second day one of the two tubes growing at each temperature was tested with iodin potassium iodid for starch. All behaved alike. In the portions of the cylinder covered by the stroma there was practically no starch reaction, i. e., there was only the faintest purplish stain in a few cells, so slight as to have been easily overlooked. The tissue of the potato was much softened and was penetrated by hyphæ (Pl. IX, fig. 4). The microscopical characters resembled those of cultures grown at room temperature (described under growth on steamed potato cylinders, p. 26).

INOCULATION EXPERIMENTS.

Inoculations have been made on lime, orange, pomelo, lemon, kumquat, tangerine, and *Citrus trifoliata*. These have been numbered in two series, one comprising those made with the lime strain, the other with the strain isolated from the orange. A detailed account of the experiments follows.

INOCULATIONS (LIME STRAIN) ON LIME, DECEMBER 1, 1904.

The first inoculations were made on three healthy lime trees obtained from Florida; grown for some time in a bed in one of the Department greenhouses. The trees were about 3 to 4 feet tall and were making a good growth. The cultures used were: (1) Culture 6 weeks old on sterile lime wood (Pl. VII, fig. 1); and (2) beef-bouillon culture 2 months old. In both cases the fungus had been growing on artificial media 2 months (isolated October 1, 1904). The inoculations were made as follows:

No. 1, Tree I, on young growing wood 4 inches from the end of a growing branch. A small T-shaped cut was made in the bark with a sterile knife and mycelium inserted. The bark was smoothed down again and the stem wound with raffia, which completely covered the wound.

No. 2, Tree I, on new green wood just below a fork, one branch of which was 7 inches long, the other (on which was inoculation No. 1) 12 inches in length. Inoculation made as in No. 1.

No. 3, Tree I, on an older branch with grayish bark, 2 inches from the trunk. Diameter of inoculated branch, three-fourths of an inch. Inoculated like No. 1.

No. 4, Tree I, on a stem similar to No. 3, but somewhat smaller. Inoculated like No. 1.

No. 5, Tree II, on a rather old stem with gray bark, three-fourths of an inch in diameter. Inoculated like No. 1.

No. 6, Tree III, on a younger branch with green bark. Inoculation made by pricking the stem three times with a sterile needle, then placing a little mycelium over these punctures and binding with raffia.

Nos. 1 to 6 were inoculated from the lime-wood culture.

No. 7, Tree II, on a low side branch 8 inches long. Inoculation midway on stem, made like No. 1.

No. 8, Tree I, on the trunk about 3 feet from the ground. Mycelium bound with raffia on an old wound where a branch had been broken off.

No. 9, Tree III, on a branch with gray bark. Inoculated near the trunk by removing a small piece of the outer bark and binding mycelium over the cut surface.

No. 10, Tree II, on a gray stem near the trunk. Inoculation made by cutting off a very small amount (2 to 3 sq. mm.) of the outer bark, then spreading the mycelium over this injury and binding it with raffia.

Nos. 7 to 10 were inoculated from the beef-bouillon culture.

A year after the inoculation (December 1, 1905) characteristic knots had formed in every case except No. 8, in which no new wound was made. Some of these knots were then 1½ inches in diameter and resembled in every particular those received from Jamaica. No. 4 was photographed (Pl. IV, fig. 2) and pure cultures of the fungus were obtained from it.

From both Nos. 4 and 7 a witches'-broom had been produced. In No. 4 there had been an extensive growth of the main stem beyond the knot, but in No. 7 there had been none.

Tree I was photographed on March 31, 1906 (Pl. III).

On April 14, 1906, one year and four and one-half months after inoculation, the following detailed observations were made:

No. 1. Knot about 1¼ inches in diameter. The surface is rather rough and somewhat cracked, and the color is quite a dark brown or almost black in places. There are about 4 feet of growth beyond this knot, all of which is dead. This is the first knot which has caused the death of that portion of the limb beyond it.

No. 2. This knot is on the trunk of the tree and is somewhat larger and lighter in color than No. 1. It has not caused the death of the wood beyond it.

No. 3. Knot on the trunk about 1¾ inches in diameter. It is somewhat cracked and lighter in color than the bark on the adjoining stem. About half a dozen shoots are growing out of it, all of which are apparently healthy.

No. 4. Cut out on December 1, 1905.

No. 5. Knot about 1 inch in diameter, badly cracked and dark in color. A witches'-broom has formed and one of the shoots is about 4 feet long.

No. 6. Knot about 1 inch in diameter and quite irregular in shape; surface smooth and lighter colored than the surrounding bark; witches'-broom from this knot also.

No. 7. Removed December 1, 1905.

No. 8. No knot. This is the one inoculated on the old healed wound.

No. 9. Knot 1½ inches in diameter; surface smooth and light colored. One of the several shoots which has grown from this knot is about 8 feet long and as thick as a man's thumb at the base.

No. 10. Knot about an inch in diameter, very rough and scarred. A portion of the surface is almost black, while the remainder is very light colored. There are several shoots growing from this knot, one of them being over 3 feet in length. None of the growth above the knot shows any signs of disease.

On November 17, 1906, nearly two years after inoculation, all parts of the trees above the knots, with the exception of No. 5, were dead or showed signs of disease. Inoculation No. 9 on a branch at the base of one of the largest trees (Tree III) at this time was a knot nearly the size of a man's fist. Gum was oozing from it in numerous places and one of the branches above this inoculation, bearing another knot (inoculation No. 6) had been dead for many weeks. The remaining parts of this tree were still green but were making little or no growth. The leaves were very flabby and turning yellow. They were beginning to curl and dropped very easily. A large branch below the knot was very green and growing rapidly, a striking contrast to the branches above the point of inoculation, where the new growth, if any, was not at all vigorous, the young leaves being almost devoid of chlorophyll.

This tree (Tree III) at this time furnished a most interesting example of the effect of inoculation with the lime-knot fungus. Inoculation No. 6, on one of the smaller limbs, had caused the death of the branches above it some months before. The trunk of the tree, which bore a very large knot near the base, the result of inoculation No. 9, was dying, while one large branch springing from a point below the knot was apparently as healthy as ever.

Nos. 5 and 10, on Tree II, had grown into large knots and the branches above No. 10 were all dead. No. 5, which was on one of the branches of the fork of the trunk of Tree II, was a much smaller knot than No. 9, described above. The parts of the tree above No. 5 were still green and apparently healthy.

On Tree I all of the branches above inoculations Nos. 1 and 2 were dead; the rest were green and healthy.

On September 17, 1907, nearly two years and ten months after inoculation, the trees were still alive and were then growing rapidly. The portions above the inoculations were dead in most cases, but many branches had grown out below these centers of infection. Many secondary knots had appeared on one of the trees (Tree II). These extended from the ground, where they occurred in the greatest numbers, all the way up the trunk, and they varied in size from half an inch to 2 inches in diameter. Young shoots had grown from many of the knots.

In July, 1908, it became necessary to remove the lime trees from the bed in which they had been growing and, believing that the experiment had continued long enough, they were cut out. The condition of the one showing the greatest number of knots (Tree II) was as follows:

The main stem had a diameter at the surface of the earth of 2½ inches and a diameter at the height of 1 foot above the surface of 1½ inches. This diameter was preserved upward for about 40 inches from the earth. About 3 feet from the ground on a branch of the fork of the main stem was inoculation No. 5, and on a smaller branch given off just below it was No. 10, these tumors being dried out and black. At the fork the inoculated branch was three-fourths of an inch in diameter, while the uninoculated one had a diameter of 1¼ inches.

The most striking thing in connection with the stem was the great number of secondary tumors occurring throughout a distance of about 3 feet. The surface of the stem was almost entirely covered with them. There were 100 or more. The exact number can not be stated, because of fusions. A few of these secondary tumors were dead, but nearly all were living and covered by a grayish white bark, occasionally somewhat fissured. The length of these secondary tumors varied somewhat, being from three-fourths of an inch to 1½ inches; their breadth from half an inch to 1 inch or more; and their height from one-fourth to three-fourths of an inch. Most of them were elliptical in outline, the longest axis being in the direction of the long axis of the stem. These swellings, as already stated, were attached by a wide base firmly to the wood of the stem. Some of these secondary tumors were sending out feeble shoots, half a dozen to a dozen or more in places. One vigorous shoot from the base of the stem had a basal diameter of three-fourths of an inch and a length of 5 feet or more. There were some secondary swellings at the base of the stem and two tumors of moderate size about 1½ feet above the base. It was at first thought that these might be the result of more recent natural infections because of the distance between the tumors, but microscopical examination revealed the presence of the fungus in the wood in small quantities throughout the intervening space. Six inches farther up the main stem another vigorous shoot had attained a length of 4 feet or more and bore two small secondary tumors near its base. The general appearance of the trunk of this tree is well shown in the photographs, which, however, were made from the shrunken, dried-out stem (Pls. V and VI).

Gum was oozing from the stem in places, but not more than one would expect in cases of wounds due to other causes.

A year later, July 22, 1909, the fungus was isolated from one of the secondary knots on the trunk of this tree (Tree II), which was cut down the previous year and has been in the dry laboratory ever since. Thus the mycelium has lived in these knots at least 2 years—1 year dry. Inoculations made with this isolation on tender shoots of lime and pomelo on July 29, 1909 (see p. 57), produced within 3 weeks unmistakable tumor tissue and mature pycnidia and spermagonia.

Summary.—All of the inoculations with the exception of No. 8, in which no wound was made, have been most successful. The observations extended over a period of 3½ years. In the majority of cases the portion of the tree above the knot was dead and many witches'-brooms had formed both from the artificial infections and the secondary knots. The fungus was traced through the stem for a distance of 5 feet beyond the point of inoculation (Pl. V, x to x′).

INOCULATIONS (LIME STRAIN) ON LIME AND ORANGE, DECEMBER 12, 1905.

On this date 10 more inoculations were made, 5 (Nos. 11 to 15) on lime and 5 (Nos. 16 to 20) on orange. None of the trees had ever been inoculated, and all were free from knots. Inoculations were made by making a T-shaped cut in the bark, inserting mycelium, and binding the wound with raffia. A bouillon culture of the fungus made on December 1, 1905, directly from one of the artificial infections in the greenhouse,[1] was used for the inoculations. The orange trees had been recently transplanted and were in a dormant state. There were no young, growing shoots on them.

On April 14, 1906, four months after inoculation, all the inoculations on the limes were taking, as follows:

No. 11. Slight but distinct swelling at the point of inoculation.

No. 12. Swelling about the size of a split pea and lighter colored than the rest of the stem. The limb beyond the knot was somewhat stunted.

No. 13. Slight but distinct swelling at the point of inoculation. Diseased area lighter colored than the surrounding bark.

---

[1] No. 4, December 1, 1904.

No. 14. Knot about half an inch in diameter, light in color. Very little growth has been made beyond the point of inoculation.

No. 15. Slight swelling for about half an inch along one side of the stem. No definite knot, although there was slightly more swelling at the exact point of inoculation.

There were no signs of disease on the orange trees (varieties not recorded), and with the exception of No. 16, where there was very slight swelling, it was most difficult to determine the point of inoculation.

Seven months later there were still no signs of infection on the oranges.

On September 17, 1907, No. 11 (lime) bore a small knot the size of a kernel of corn. In No. 12 there was a small rough knot at the point of inoculation and a slight swelling extending along the branch for a short distance.

November 13, 1908.

Limes. Trees not growing well.

Nos. 11 and 12. Tumors have increased little, if any, in size during the past year.

No. 13. Tumor tissue, but no true knot.

No. 14. Missing. Had a knot about half an inch in diameter four months after inoculation.

No. 15. Missing. Tumor tissue four months after inoculation.

Summary.—Limes. Small knots formed in three of the five lime inoculations and tumor tissue in the other two.

Oranges. No infection, with the possible exception of No. 16, in which there was slight swelling. The trees were not in good condition when inoculated.

INOCULATIONS (LIME STRAIN) ON POMELO, LEMON, CITRUS TRIFOLIATA, KUMQUAT, AND LIME, JULY 5, 1906.

Inoculations were made on pomelo, lemon, *Citrus trifoliata,* kumquat, and lime. Pure beef-bouillon cultures made directly from a small artificially produced knot were used and inoculations were made on twigs and leaves. In the former the method used in the earlier experiments was employed.

Nos. 21 to 25 (pomelo, Duncan variety). The trees were small and had been set out but a short time, so were not growing rapidly. No. 25 was inoculated on a leaf. The midrib was pricked and mycelium was placed over the wound.

Nos. 26 to 30 (lemon, Villa Franca variety). These trees were also small and making little growth. No. 30 was made on a leaf in a manner similar to No. 25.

Nos. 31 to 35 (on a seedling lemon 8 to 10 inches high). It was very healthy and growing rapidly. Nos. 33 and 35 were made on leaves.

Nos. 36 to 40 (*Citrus trifoliata*, two trees). No. 40 was on a leaf, the other four on the stem.

Nos. 41 to 45 (Japanese kumquat). All inoculations on twigs.

Nos. 46 to 48, 51, and 52 (old lime trees). Nos. 46 to 48 were made on leaves, the others on twigs.

On November 7, 1906, the following observations were made on these inoculations:

Nos. 21 and 22 (pomelo). Slight swelling at the point of inoculation.

No. 23 (pomelo). Stem considerably swollen for about half an inch.

No. 24 (pomelo). The branch in which this inoculation was made has grown 1½ feet during the summer. Point of inoculation could not be found.

No. 25 (pomelo leaf). No evidence of infection.

Nos. 26 to 35 (lemon). No signs of disease.

No. 36 (*Citrus trifoliata*). Slight swelling at the point of inoculation.

No. 37 (*Citrus trifoliata*). Slight swelling about one-half inch long.

No. 38 (*Citrus trifoliata*). Small knot about the size of a small pea. The effect produced here by inoculation is, at this date, greater than on the limes inoculated at the same time.

No. 39 (*Citrus trifoliata*). Slight swelling at point of inoculation.

No. 40. No record.

The *Citrus trifoliata* plants, as a whole, are not very healthy, but one or two branches are making good growth.

No. 41 (kumquat). Slight scar, no swelling.

No. 42 (kumquat). Very little swelling at point of inoculation.

No. 43 (kumquat). Like No. 41.

No. 44 (kumquat). Very little, if any, swelling.

No. 45 (kumquat). No scar. Point of inoculation not distinguishable.

Nos. 46 to 48 (lime leaves). No signs of infection.

Nos. 51 and 52 (lime twigs). Slight swelling at point of inoculation.

On September 17, 1907, one year and two months after inoculation, the following observations were made:

Nos. 21 and 22 (pomelo). Slight swelling.

No. 23 (pomelo). A large irregular scar about 1 inch long and half an inch wide. This is considerably swollen. The fungus has apparently made some headway here, although it has failed to produce a knot.

No. 24 (pomelo). No infection.

Nos. 31 to 35 (lemon). No results from inoculation. In most cases the point of inoculation is not distinguishable.

No. 36 (*Citrus trifoliata*). Very slight swelling at point of inoculation.

No. 37 (*Citrus trifoliata*). Little, if any, swelling.

No. 38 (*Citrus trifoliata*). Small knot about the size of a pea and similar to the smaller knots on the lime trees. This has grown very little in the last 10 months. The surface of the knot is light in color, rough and cracked, and resembles in every way that of the knots on lime.

No. 39 (*Citrus trifoliata*). Very little swelling.

Nos. 41 to 45 (kumquat). No evidence of infection.

Nos. 51 and 52 (lime twigs). No record.

November 13, 1908. Nos. 21 and 22 (pomelo). Slight swelling.

No. 23 (pomelo). Considerable swelling, but no real knot.

No. 24 (pomelo). Could not find point of inoculation.

Nos. 26 to 29 (lemon). No infection. No scar in Nos. 26, 27, and 29.

Nos. 31 to 35 (lemon). Place of inoculation not discoverable.

No. 36 (*Citrus trifoliata*). Knot about three-fourths of an inch long, one-fourth of an inch high, and three-eights of an inch wide, extending over half way around the stem. It is light colored with a fairly smooth surface and resembles the smaller knots on lime. It is the largest knot which has been produced on *Citrus trifoliata*.

No. 37 (*Citrus trifoliata*). Not a real knot, but there has been much more than an ordinary wound reaction. Swelling one-eighth of an inch high. (Nos. 36 to 39 are on the same plant.)

Nos. 41 to 45 (kumquat). Inoculation places not found.

No. 51 (lime). No knot, only slight swelling.

No. 52 (lime). Label has fallen off, so could not be sure of the point of inoculation. There is a slight swelling on one of the branches, but no true knot anywhere on the tree. Either none has been produced or it has been cut off by the gardener.

November 10, 1909. On this date the trees were removed to another greenhouse, and the following notes were made by Dr. Smith:

> No. 23 (pomelo). Well-defined small tumor at the point of inoculation. This is about 5 mm. in diameter, and as high. Two cm. above and below are similar small secondary tumors.
>
> No. 37 (*Citrus trifoliata*). Some small tumors in the scar tissue.
>
> No. 38 (*Citrus trifoliata*). Slight but distinct tumor in the scar tissue. It is raised up above the level of the stem about 4 mm. and has a diameter either way of about 6 mm.
>
> July 20, 1910. No. 37 (*Citrus trifoliata*). Small tumors and much tumor tissue in the wound. Swollen area is 1.5 cm. long by 5 mm. wide by 3 mm. high.
>
> No. 38 (*Citrus trifoliata*). Small knot 6 mm. in diameter.
>
> No. 39 (*Citrus trifoliata*). Swelling 6 mm. by 6 mm. by 1 mm. high.

Summary.—The result of this set of inoculations may be summed up as follows:

TABLE III.—*Results of inoculations of July 5, 1906.*

Kind of tree.	Knot.	Swelling.	Failure.
Pomelo	1	2	1
Lemon	0	0	7
Citrus trifoliata	3	1	0
Kumquat	0	0	5
Lime	0	2	0

INOCULATIONS (LIME STRAIN) ON LEMON, POMELO, CITRUS TRIFOLIATA, AND LIME, JUNE 23, 1908.

Inoculations were made with the fungus isolated March 11, 1908, from a secondary tumor on one of the trees first inoculated in the greenhouse. A slit was made in the bark with a small sharp knife and bits of mycelium from a corn-meal culture 8 days old were inserted into the wounds, which were then bound with raffia. The inoculations were numbered as follows:

Nos. 53 to 58, lemon, Villa Franca variety.
Nos. 59 to 63, pomelo, Duncan variety.
Nos. 64 to 67, pomelo, Duncan variety (on another tree).
Nos. 68 to 71, lemon, Villa Franca variety.
Nos. 72 and 73, pomelo, Duncan variety.
Nos. 74 to 76, lemon, Villa Franca variety
Nos. 77 to 82, *Citrus trifoliata.*
Nos. 83 to 88, lime.

Most of the inoculations were made on the younger growth, but some were on the older part of the branch. No entirely sound lime tree was available for inoculation, but the young growth of the one least affected was used for this purpose. No tender, rapidly growing shoots on the trees.

August 4, 1908. Knot beginning to form on No. 61 (pomelo); cut off and put into alcohol.

October 14, 1908. The lemons show little or no results from the inoculation. On some of the pomelos, however (Nos. 59, 62, 63, 65, and 72), knots appear to be forming. The inoculations on *Citrus trifoliata* have also caused some swelling, but it is less than that on the pomelos. The limes inoculated as checks were destroyed at the time of the removal of the trees from one greenhouse to another.

October 15, 1908. Nos. 66 and 81 cut off and put into alcohol. Both show slight swelling.

November 13, 1908. The inoculated trees appeared as follows:

Lemon:

No. 54. Very little swelling, probably wound reaction only.

No. 55. Slight swelling; appears to be more than mere wound reaction.

No. 56. Like 55.

No. 57. Like 54.

No. 58. Slight swelling.

Nos. 68 to 70. Little or no swelling.

No. 71. Some swelling. It may be only wound reaction.

Nos. 74 to 76. Very little swelling, probably only wound reaction.

Pomelo:

No. 59. Slight swelling, but looks like more than a wound reaction.

No. 60. Swelling 8 mm. long and about 4 mm. high. Knot seems to be forming.

No. 61. Cut off August 4.

No. 62. Swelling about 1½ cm. long and about 2 mm. high.

No. 63. Swelling extending about half way around the branch. It is about 2 mm. high.

No. 64. Considerable swelling, about 8 mm. long.

No. 65. Swelling about 1½ mm. long.

No. 66. Cut off October 15, 1908.

No. 67. Slight swelling. (Made on the trunk.)

No. 72. Small knot about 4 mm. in diameter.

No. 73. Little, if any, swelling.

Nearly all of the pomelos look as though knots were forming.

Citrus trifoliata:

Nos. 77 to 79. Considerable swelling. Knots probably are forming.

No. 80. Slight swelling.

No. 81. Cut off October 15, 1908.

No. 82. Slight swelling.

Nos. 77 to 79 are on one tree; Nos. 80 to 82 on another.

December 2, 1908. End of pomelo branch on which is inoculation No. 60 is dead. A small knot about 1 mm. long and 2 cm. high. Cut off.

February 11, 1909. No change.

August 20, 1909 (14 months).

Lemon. In no case has a knot formed. On some of the inoculated branches there has been a slight swelling, but it is little, if any, more than a wound reaction. Immature pycnidia are present on Nos. 68 and 70.

Citrus trifoliata. Two fairly good small knots have formed on the *Citrus trifoliata* trees. One (No. 77) measures 5 by 3 by 2 mm. and another (No. 79) measures 8 by 4 by 2 mm., ca. In No. 77 a second small swelling 3 mm., ca., in diameter, is present. The rest of the *Citrus trifoliata* inoculations show more or less swelling, and in one case (No. 80) there are a few mature pycnidia.

Pomelo. There has been little, if any, increase in the amount of swelling since November, 1908, at which time considerable tumor tissue had formed. Immature pycnidia formed on the bark of No. 64.

A year later, November 10, 1909, the following observations were made by Dr. Smith prior to the removal of the trees to another greenhouse:

No. 62 (pomelo). Scar bears in its upper portion a well-defined small tumor. This is a roundish one about 5 mm. in diameter and about 4 mm. high.

No. 63 (pomelo). Swollen at the point of inoculation but no well-defined tumor. About 2 inches above, at the origin of the leaf, there is a small nodosity covered with buds.

No. 65 (pomelo). The whole punctured area, which is about 2 cm. long, has developed a stunted tumor, which has not grown any recently. (Inoculation on a terminal shoot which has made no growth.)

No. 73 (pomelo). At the extreme upper part of this scar there is a well-developed small tumor about 4 mm. in diameter. (Inoculation is at the base of a branch half an inch in diameter.)

No. 77 (*Citrus trifoliata*). This inoculation, 3 feet from the end of a small shoot, bears two distinct tumors in the scar. They are rounded up, a gray white, and as plain tumors as any we have ever obtained, although yet small. The largest one is about 6 by 5 by 4 mm. The other is about half the size.

No. 78 (*Citrus trifoliata*). Small shoot with slight evidence of tumor tissue in the scar.

July 20, 1910. No. 77 (*Citrus trifoliata*). Two good, though small knots, one 6 by 6 by 4 mm., the other nearly as large. These are on the lips of the wound.

No. 78 (*Citrus trifoliata*). Tumor tissue.

No. 79 (*Citrus trifoliata*). Knot 9 by 7 by 3 mm.

August 14, 1910. No. 77 (*Citrus trifoliata*). Surface covered with pycnidia, containing the large, hyalin, 1-celled spores. Cut off and taken into the laboratory.

Summary.—Pomelo. Small but distinct tumors formed at 6 of the 11 points of inoculation and more or less tumor tissue at 4 others. One was doubtful.

Citrus trifoliata. Good, though small, knots in two of the six inoculations and tumor tissue in the other four. Pycnidia.

Lemon. No knots and little, if any, swelling.

Lime. Lost or destroyed during the removal from one hothouse to another early in the course of the experiment.

INOCULATIONS (LIME STRAIN) ON LIME, JUNE 27, 1908.

Another set of inoculations was made on limes. These were young trees (Tahiti and Florida seedling) which had just been received from the nursery and they had been cut back severely for transplanting. All the young twigs had been removed, so that all the inoculations were made on the trunks. The method employed was the same as in the preceding experiments.

Nos. 89 to 94 were inoculated from corn-meal flask culture 2, June 15, 1908.

Nos. 95 to 100 were inoculated from corn-meal flask culture 3, June 15, 1908.

Both cultures were descended from an isolation made March 11 from one of the secondary tumors occurring on one of the trees first inoculated.

November 13, 1908. With the exception of the two trees on which are inoculations Nos. 95 and 100, all have died back below the point of inoculation. On these two trees, however, knots appear to be forming.

No. 95. Swollen place about 1½ cm. long and 2 mm. high. This is still partially covered by the old bark, which has become lighter in color.

No. 100. Shows only slight swelling, but knot seems to be forming.

August 20, 1909. There has been no increase in the amount of tumor tissue within the last nine months.

Summary.—Tumor tissue formed in two cases. In all the others the trees which had been pruned for transplanting died back to a point below the place of inoculation.

INOCULATIONS (LIME STRAIN) ON LEMON, TANGERINE, AND KUMQUAT, JULY, 1908.

Inoculations were made by the gardener under Dr. Smith's direction. Pieces of bark, including a bit of the wood from young lime knots, were grafted into some trees in the orange house.

December 2, 1908. The following notes were made by Dr. Smith:

> Lemon (American Wonder variety). In each of the three inoculations on lemon (all on the same tree) small tumors have formed in the scar tissues. The largest is now 8 mm. long, 4 mm. wide, and 4 mm. high. These have doubled in size in the last six weeks.
>
> Tangerine (St. Michael). One of the two inoculations looks hopeful.
>
> Kumquat. No swelling at points of inoculation.

February 11, 1909.

Lemon. The tumors in the scar tissues have increased very much in size. The largest is about 2 by 1½ by 1 cm. high. Gum is oozing from some of them.

Tangerine. Knots forming very slowly, if at all. One of the inoculations looks hopeful.

Kumquat. Very little swelling.

June 16, 1909. Photographed one of the knots on lemon (Pl. X). They have increased comparatively little in size in the last few months. This tree was a very vigorous lemon only a few years old and therefore was supposed to be in good condition for infection.

August 20, 1909.

Tangerine. In one of the wounds a knot 5 mm. in diameter has formed. The edges of the cut are considerably swollen in both inoculations.

Kumquat. Considerable swelling in the wound in one inoculation. No reaction at all in the others.

November 10, 1909. Dr. Smith made the following notes on the lemon prior to its removal to another greenhouse:

> Considering the length of time which has elapsed, the development of the knots on this variety of lemon has been very slow. The conditions at present are as follows: Tree full of fruit, which is of very large size. The lowest point of inoculation is about 3 feet from the ground in stem now nearly 2 inches in diameter. The scar bears irregular tumor tissue not much elevated: also a central, well-developed, rounded-up tumor which is about 2 cm. by 2 cm. by 15 mm. high. About one-fifth of a foot up the stem is another scar, which bears eight small tumors varying in size from 1 to 1.2 cm. in diameter. The third wound, on another branch, bears two small tumors on one side of the scar. These are each about 1 cm. in diameter.

January 27, 1911. The knots on the lemon have increased in size astonishingly of late, considering the slow rate at which they have developed hitherto. The largest knot is now about 2.5 cm. in diameter.

Summary.—Lemon. Excellent tumor formation in every case.

Tangerine. Small tumor in one case and tumor tissue in the other.

Kumquat. Small amount of swelling in one instance; otherwise no result.

INOCULATIONS (ORANGE STRAIN) ON LIME, FEBRUARY 24, 1909.

Twelve inoculations were made on lime trees with the fungus isolated January 14, 1909, from orange knots received from Jamaica. A potato-agar slant culture 28 days old was used for the purpose, and the inoculations were made in the way described under the lime-knot-fungus inoculations. Nos. 3 and 10 were made on the trunk and the others on the youngest green twigs available. The inoculations were made on trees which had been growing in the greenhouses for about eight months. There were no tender, rapidly growing shoots.

On April 15 there was noticeable swelling at the point of inoculation, and four weeks later (May 13) signs of infection were unmistakable in the following:

No. 1. Knot about 1 cm. long and 0.75 cm. thick.

No. 2. Much less swelling than in No. 1, but knot appeared to be forming.

No. 4. Stem at point of inoculation swollen to about twice the diameter of the rest of the branch.

No. 5. Slight swelling, but indicative of knot formation.

Five months after inoculation (July 29) inoculation No. 1 was removed. It had increased very little in size since May, but in the mean time the branch bearing it had died.

Microscopical examination of the knot showed the black mycelium present in abundance, especially in the inner layer of bark.

On August 13, 1909, all the inoculations with the exception of the two on the trunk (Nos. 3 and 10) and one other (No. 12) showed signs of infection, as follows:

No. 2. Knot about 1.25 cm. long and 0.75 cm. thick.

No. 4. Good small knot about 1 cm. long and 0.5 cm. thick.

No. 5. Considerable swelling.

No. 6. Considerable swelling.

No. 7. Slight swelling.

Nos. 8 and 9. Considerable swelling, knots clearly forming.

No. 11. Slight swelling.

There was at this date a striking difference between this set of inoculations and those made with the lime-knot fungus 24 hours later (Feb. 25, 1909, see p. 53). In the latter there was only very slight swelling at the point of inoculation. Potato-agar slant cultures 4 weeks old were used in both cases. The orange strain used in this set of inoculations, however, had been isolated only six weeks, whereas the lime strain used for the inoculations of February 25 had been growing for 11½ months on artificial media.

On November 10, 1909, the following notes were made by Dr. Smith prior to the removal of the trees to another hothouse:

No. 2. Two well-developed small tumors, each about 1 cm. in diameter. The inoculated branch is small and stunted (about 4 mm. in diameter).

No. 4. The scar bears a distinct tumor about 1.5 cm. by 8 mm. by 4 mm. high.

No. 5. A distinct tumor in the scar. It is about 2 cm. long and not much raised above the surface of the stem.

No. 6. Stunted small shoot bearing a distinct small tumor in the inoculated part.

No. 7. The scar has welled-up edges, suggestive of tumor tissue.

No. 8. A stunted small shoot. Distinct tumor tissue in the scar.

No. 9. Shoot stunted. Tumor tissue in the scar.

No. 11. Distinct small tumor at the base of the shoot.

No. 12. The extreme tip of the shoot has not grown any. No tumor.

On July 20, 1910, the trees were just beginning to recover from the shock of transplanting and were beginning to put out new shoots. The following observations were made on that date:

No. 4. Little, if any, growth of the tumor since November, but that part of the inoculated branch above the knot (20 cm.) is dead. Mature pycnidia are present on the surface of the knot, and microscopical examination revealed the mycelium extending 12 cm. above the tumor.

No. 5. Little, if any, change since November.

No. 6. Tumor tissue 8 cm. long by 4 mm. wide by 3 mm. high, making the inoculated portion of the stem twice the size of the rest of the branch.

No. 7. Knot 8 by 6 by 4 mm. There is also in the wound a second knot about half the size, with considerable swelling of the stem between the two.

No. 8. The inoculated portion of the stem is swollen and there are two knots in the wound. One is 0.5 cm. in diameter and the other about 7 by 4 by 2 mm.

No. 9. Considerable tumor tissue in the wound.

No. 11. Knot 8 by 8 by 4 mm.

Summary.—Typical tumor formation in 9 of the 12 inoculations. The inoculated shoots were stunted and in one instance all of that portion beyond the knot (20 cm.) died. The black mycelium was traced through it for 12 cm. beyond the knot. Two of the inoculations which failed to cause infection were on the trunk and the third was on a shoot which made no growth after the inoculation. Mature pycnidia were observed on one tumor only (No. 4).

INOCULATIONS (LIME STRAIN) ON LIME, FEBRUARY 25, 1909.

On this date 12 inoculations (Nos. 101 to 112) were made on small lime trees which had been growing in the greenhouse since June, 1908. Three trees were inoculated. Two of the inoculations were on the trunk, the rest on fairly young green shoots, and were made in the manner previously described. No tender, rapidly growing shoots on the trees. Mycelium from a potato-agar slant 29 days old was used (descended from an isolation of March 11, 1908).

August 13, 1909. There was very slight swelling in all except the two trunk inoculations. Knot seems to be forming slowly in No. 105.

November, 1909. Trees transplanted. No record.

July 7, 1910. No knots have formed. The whole branch bearing inoculations Nos. 102 and 103 is dead.

Summary.—No formation of tumor tissue. The trees were small and stunted at the time of inoculation, and some months later several of the branches (uninoculated as well as inoculated) were dying.

The failure of the inoculations may be due to this condition of the trees or to loss of virulence of the fungus, this strain having grown 11½ months on artificial media.

INOCULATIONS (LIME STRAIN) ON LIME, JULY 21, 1909.

Three very young tender shoots on one of the old lime trees were inoculated. This tree had been previously inoculated, but with little success. It had not been growing well previously, but it was at this time putting forth a few vigorous shoots. Potato-agar culture 7 weeks old was used (descended from isolation of March 11, 1908).

August 13, 1909. No. 113. Stem swollen at point of inoculation to one and one-half times the diameter of the rest of the shoot.

No. 114. Considerable swelling; shoot not growing well. Cut out and examined microscopically. Mycelium found in the tissues.

No. 115. Little, if any, swelling.

The shoots grew very rapidly for a few days after inoculation, but are now growing slowly, if at all.

July 7, 1910. No. 113. Considerable swelling.

No. 115. Very little swelling.

Summary.—More or less swelling, but no knots were produced. This is the same strain used for the lime inoculations of February 25, 1909. It has now been growing on artificial media for 14⅔ months and it is quite probable that it has lost its virulence.

INOCULATIONS WITH PYCNOSPORES (ORANGE STRAIN) ON LIME AND POMELO, JULY 21, 1909.

The inoculations were made from a potato culture (originating from a single spore) 6 days old, the surface of which was thickly dotted with round white masses of the large, colorless, one-celled spores discharged from the pycnidia buried in the stroma. This strain was isolated six months prior to the date of these inoculations. A slit was made in the bark with a sterile knife and a quantity of mycelium and spores inserted. Wound bound with raffia. The inoculations were numbered as follows:

Lime:

Nos. 13 and 14, on same tree, bearing only fairly young branches. No tender shoots.

Nos. 15 to 17, on second tree, bearing only fairly young branches. No tender shoots.

Nos. 18 to 20, on very tender shoots on a third tree.

Pomelo:

Nos. 21 and 22, on young branches of pomelo previously inoculated with lime-knot fungus with little or no effect. These branches or shoots were young, with leaves still pale green, but had already become woody.

All of these trees had been inoculated before, but no large knots or even fair-sized ones had been produced and no secondary knots ever formed. There were very few tender shoots on the trees, but some were beginning to push out. Eight days after inoculation the shoots were growing rapidly and gum was exuding from the wounds.

On August 13, 1909, three weeks after inoculation, the fungus was fruiting on three of the stems (Nos. 15 to 17). There was a slight swelling of the woody tissues, and the black mycelium had grown all through the strip of bark cut for the insertion of the inoculating material and had produced pycnidia filled with the characteristic large, hyalin, 1-celled spores. Some of the pycnidia were buried deeply in the bark tissues; others were bursting through the epidermis. There was no stroma and little or no subiculum. The epidermis had turned grayish white. The detailed observations of the inoculations are as follows:

Nos. 13 and 14. Slight swelling. Not very vigorous shoots.

No. 15. Slight swelling. Small amount of gummy exudate. Pycnidia breaking through the epidermis.

No. 16. Slight swelling. No gum. Pycnidia breaking through the epidermis.

No. 17. Resembles No. 16, but there is less swelling. No gum. Pycnidia breaking through to the surface.

No. 18. Broken off some days ago. There was slight swelling.

No. 19. Some swelling. No gummy exudate.

No. 20. Considerable swelling. Large amount of gum.

Nos. 21 and 22 (pomelo). Little, if any, swelling.

Measurements were made of the pycnidia and pycnospores from inoculation No. 15. The former measured 152 to 192 μ by 152 to 160 μ, the latter 20 to 32 μ by 8 μ.

August 20, 1909.

Lime.

Nos. 13 and 14. No change.

No. 15. Edge of the wound much swollen. Mature pycnidia.

No. 16. Good production of tumor tissue. Mature pycnidia.

No. 17. Considerable tumor tissue. Mature pycnidia.

No. 19. Considerable tumor tissue.

No. 20. Stem at point of inoculation is twice its normal size.

Pomelo.

No. 21. Considerable tumor tissue. Mature pycnidia bursting through the epidermis, which has become grayish white. The tissue beneath it is so full of the black mycelium that it appears black.

No. 22. Little, if any, swelling. Tissues appear black.

Gum is no longer exuding and has not been produced in any inoculations additional to those noted on August 13.

November 10, 1909. Notes made by Dr. Smith prior to removal of trees to another hothouse:

No. 13. Twig growing very slowly. Definite small tumor, but it is not growing very rapidly. It is 1 cm. by 3 mm. by 3 mm. high and covers the whole wound.

No. 14. Upper half of the inoculated place bears a distinct small tumor about 5 by 4 by 3 mm. Twig stunted. Scarcely any growth since inoculation.

No. 15. This inoculation has made marked progress since August 13. There is no longer a particle of doubt that the spores found in cultures of the orange strain belong to the life cycle of this fungus. The tumor is cork yellow in color, 1.5 cm. long and 1 cm. wide in the widest portion, and nearly surrounding the stem, which is not over 2 to 3 mm. in diameter.

No. 17. Decided growth in the last 1½ months. Tumor is now a greenish white, cracking open, and nearly 1 cm. in diameter. The stem is about 3 to 4 mm. in diameter. There is a similar tumor on the other side of the stem a little lower down, i. e., at the extreme base of the point inoculated.

No. 20. There has been evidence of a small tumor. Shoot has not made much growth.

July 7, 1910. The trees are just beginning to recover from the removal to the new greenhouse and are putting forth new shoots.

Lime.

No. 13. Inoculated shoot dead. It has made little, if any, growth since inoculation. The dead tip, which is 6.5 cm. long, is covered with pycnidia full of the large hyalin continuous spores. The tumor has increased little, if any, in size since November, 1909.

No. 14. Inoculated tip (6.5 cm. long) is dead and covered with pycnidia. The tumor has increased little, if any, in size in the last 8 months.

No. 15. Good knot 1.5 cm. by 1 cm. by 7 mm. Swelling extends about 2 cm. beyond the knot (covering the whole wound). Small second knot also in the wound. Portion of branch beyond the knot is dead. Pycnidia buried in the wood.

No. 20. All of inoculated branch beyond the knot (5 cm. in length) is dead. Many pycnidia on the stem below the knot. The latter has increased little, if any, in size in the last eight months.

December 17, 1910.

No. 15 now bears a knot about 2 cm. in diameter.

March 9, 1911.

No. 15. Knot 4.5 cm. in diameter girdling the stem.

No. 17. End of branch dead. Removed.

Summary.—Limes. Knots were produced on all (5) that were under observation for more than a month, and tumor tissue in the three others; pycnidia appeared on six, and in five cases that portion of the branch beyond the knot died.

Pomelo. These were under observation only a month. During that period pycnidia and considerable tumor tissue formed on one, while the other showed little, if any, sign of infection.

INOCULATIONS (LIME STRAIN) ON LIME, KUMQUAT, AND POMELO, JULY 29, 1909.

On this date another set of inoculations was made on tender shoots of lime, kumquat, and pomelo. Mycelium from potato culture seven days old (isolation of July 22, 1909, from secondary knot on Tree II, inoculated December 1, 1904) was inserted into the stem in the manner previously described.

Inoculations were numbered as follows:

Lime.

Nos. 116 and 117, very young, tender shoots, not at all woody.

Kumquat.

Nos. 118 and 119, young, very slightly woody.

Pomelo.

Nos. 120 and 121, young rapidly growing shoots. One slightly woody at point of inoculation, the other not at all hard.

August 13, 1910. Slight swelling in both lime inoculations. Little, if any, in the kumquat and pomelo.

August 20, 1909. Mature pycnidia and spermagonia pushing through the epidermis in No. 116. There has been a copious growth of mycelium under the epidermis, but no stroma has been formed. There is slight but unmistakable swelling.

Both of the pomelos show a very good production of tumor tissue, considering the short time which has elapsed since the inoculation (22 days). There has been as much swelling as in inoculations of the same date made with the orange strain. In No. 120 the swelling measures 1.5 cm. by 4. mm. by 2 mm., ca., and in No. 121 it is 1 cm. by 4 mm. by 2 mm., ca.

Little, if any, swelling in the kumquats.

July 7, 1910.

No. 116. Label lost during removal to new hothouse.

No. 117 (lime). Distinct tumor tissue.

No. 120 (pomelo). Swelling 1.5 cm. by 1.5 cm. by 0.25 cm., extending half around the stem.

No. 121 (pomelo). Tumor 1.75 cm. by 0.5 cm. by 4. mm., ca. The whole tip of the branch (7.5 cm. beyond the knot and 1.25 cm. below) is dead, and thickly covered with the pycnidia of this fungus.

Summary.—Lime. Tumor tissue formed in both of the inoculated shoots, and pycnidia and spermagonia on one of them (three weeks).

Pomelo. Typical small tumors in both cases. One of the inoculated branches died and was covered with the pycnidia of *Sphaeropsis tumefaciens*. A Diplodia, closely resembling *Diplodia natalensis* Pole Evans and producing a rot of lemons and apples similar to that caused by the latter, was also found fruiting on this dead branch and isolated from it. It is plainly distinguishable from the Sphaeropsis, however, even when immature.

Kumquat. Little, if any, results from the inoculation. Under observation only 22 days, the labels being lost on removal to the new hothouse.

INOCULATIONS (NONFRUITING ORANGE STRAIN) ON LIME, KUMQUAT, AND POMELO, JULY 29, 1909.

Six inoculations (Nos. 23 to 28) were made on tender, rapidly growing shoots on trees in the greenhouse. Pieces of the stroma from a potato culture 7 days old (a second isolation, July 22, 1909, from the Jamaican orange knots, containing no spores) were inserted into slits in the bark and the wound was bound with raffia. The inoculations were numbered as follows:

Lime.

Nos. 23 and 24, shoots very tender and not at all woody.

Kumquat.

Nos. 25 and 26, young shoots but slightly woody.

Pomelo.

Nos. 27 and 28, very tender rapidly growing shoots. Leaves not entirely unfolded.

August 13, 1909.

No. 23 (lime). Considerable swelling. Small amount of gum.

No. 24 (lime). Slight swelling. Gummy exudate. Cut off and examined microscopically. Mature pycnidia bursting through the epidermis. Pycnidia measured 176 to 192 μ by 120 to 122 μ. Spores 16 to 24 μ by 6 to 8 μ.

Nos. 25 and 26 (kumquat). Little, if any, swelling.

Nos. 27 and 28 (pomelo). Slight swelling. Small amount of gum.

August 20, 1909.

No. 23 (lime). Pycnidia bursting through the epidermis in great numbers. Abundant growth of mycelium beneath the epidermis, but no stroma. Swelling about 2 mm. thick.

No. 27 (pomelo). Swelling 5 by 4 by 2 mm., ca.

No. 28 (pomelo). Swelling 1 cm. by 3 mm. by 2 mm. Gum is no longer exuding from the wounds.

Nos. 25 and 26 (kumquat). Little, if any, swelling.

August 31, 1909.

No. 23 (lime) brought into the laboratory for sections. Considerable tumor tissue.

November 10, 1909. Notes made by Dr. Smith prior to the removal of trees to another greenhouse:

> No. 27 (pomelo). On a stunted terminal shoot which has not grown much since the date of inoculation there is a distinct small tumor following the whole of the scar. This is about 1 cm. long by 8 mm. broad by 3 mm. high.
>
> No. 28 (pomelo). A small stunted branch. Overgrowth of the edges of the wound to such an extent that I think it is abnormal but not so well defined a tumor as the preceding.

July 7, 1910.

No. 27 (pomelo). Swelling 1 cm. long by 3 mm. high and extending half way around the stem.

No. 28 (pomelo). This tumor has grown little in the last 8 months. It is now about 1 cm. long by 3 mm. high and extends half around the stem.

Summary.—Lime. Tumor tissue and great numbers of pycnidia in both cases. Under observation only 22 to 30 days.

Pomelo. Small tumors in both cases. Inoculated shoots stunted.

Kumquat. Little, if any, result from the inoculation. Under observation only 22 days, the labels being lost on removal to new hothouse.

INOCULATIONS WITH PYCNOSPORES (ORANGE STRAIN) ON LIME, JULY 20, 1910.

Six inoculations were made on a lime tree which had been growing in the hothouse since June, 1908. It was putting forth many vigorous young shoots at the time of inoculation. A potato culture 9 days old which was fruiting abundantly was used (descended from isolation of January 14, 1909). The inoculations were numbered as follows:

No. 29. Vigorous young tender shoot 20 cm. long (i. e., new growth), inoculated 12 cm. from tip.

No. 30. Tender vigorous shoot 13.5 cm. long, inoculated 4.5 cm. from base.

No. 31. Vigorous tender shoot 16 cm. long, inoculated 6 cm. from base.

No. 32. Shoot young but woody, 18 cm. long, inoculated 8 cm. from base.

No. 33. Like No. 32, 21.5 cm. long, inoculated at base of shoot.

No. 34. Branch 5 mm. in diameter, inoculated at base.

Spores and mycelium were inserted into slits made in the bark or epidermis with a sterile knife. Wounds bound with raffia. Checks made also.

August 2, 1910. Inoculated shoots are vigorous and growing well.

No. 29. Considerable tumor tissue. Shoot has grown 9.6 cm. since inoculation. Mature pycnidia present.

No. 30. Broken off on July 23.

No. 31. Considerable tumor tissue. Shoot has grown 16 cm. since inoculation. Mature pycnidia present.

No. 32. Pycnidia.

No. 33. Very slight swelling.

August 17, 1910.

No. 32. Very little swelling but many mature pycnidia and a browned area extending laterally 2 mm. beyond the wound. The shoot has made no growth since inoculation. Many of the brown septate bodies (see description of fungus) are present.

No. 33. Considerable tumor tissue and many pycnidia. The shoot has not grown since inoculation.

No. 34. Slight swelling at point of inoculation.

September 6, 1910. Knots on all except No. 32, which shows only a comparatively small amount of tumor tissue.

December 17, 1910.

No. 29. Good knot 1.5 cm. long by 1 cm. wide. No growth of shoot since August 2.

No. 31. Fine knot encircling the branch and about 1.75 cm. in diameter. Surface light colored and somewhat fissured. No normal bark. No pycnidia observed at this date (present on the bark August 2). The shoot has made no growth since August 2.

No. 32. Knot 1 cm. long by 0.5 cm. wide.

No. 33. Knot about the size of No. 32.

No. 34. Excellent knot about 1.3+ cm. long by 1.3+ cm. wide. Some of the original bark remains, but it is very light colored. No pycnidia observed.

All have formed excellent knots. The check shows nothing. None of the inoculated shoots have grown since August 2. The normal bark is gone for the most part and no pycnidia were observed to-day.

January 14, 1911. Brought No. 32 into the laboratory and made cultures from it for the reisolation of the fungus. Mycelium not present in great abundance.

January 25, 1911. The strain isolated from No. 32 eleven days ago has proved to be a vigorously fruiting one.

March 9, 1911.

No. 29. Branch dying 9 cm. below and 4.5 cm. above the knot.

No. 31. Knot 3 cm. in diameter.

No. 33. Whole branch dead. Cut off.

No. 34. Knot 3 cm. by 1.5 cm. by 0.75 cm.

June 20, 1911.

No. 29. Of inoculated branch 1½ feet are dead.

No. 31. Inoculated branch is dead.

No. 34. Inoculated branch is losing its leaves and two small shoots branching from it about 3 inches above the knot are dead.

Summary.—Excellent knots on all with the exception of No. 30, which was broken off three days after inoculation. The young tender shoots which were growing well at the time of inoculation continued to elongate rapidly for at least two weeks. The more woody ones did not increase in length and had probably ceased to grow prior to the time of inoculation. Pycnidia present on three shoots within two weeks after inoculation and on a fourth two weeks later. Three of the infected branches are dead and the fourth is dying (11 months). The strain of *Sphaeropsis tumefaciens* used for these inoculations was isolated 1½ years before, but had been fruiting abundantly throughout the whole series of cultures in which it had been growing since that time. The tree was making an unusually good growth at the time of inoculation.

INOCULATIONS (LIME STRAIN) ON LIME, JULY 20, 1910.

Three inoculations were made to-day on a lime tree which had been growing in the hothouse since June, 1908. A potato culture nine days old was used.

No. 124. Young but woody branch, 2 mm. in diameter, inoculated 20 cm. from the tip.

No. 125. Young woody branch 2 mm. in diameter, inoculated at a point 12 cm. from the tip and at the base of a tiny shoot 1 cm. long.

No. 126. Woody branch 4 mm. in diameter.

Incision made in the bark with a sterile knife, and mycelium inserted. Wound bound with raffia.

July 23, 1910. No swelling.

August 2, 1910. Shoots making good growth.

August 12, 1910. Shoots vigorous and growing well. No swelling.

September 6, 1910. No tumor tissue has been produced.

December 17, 1910. No more reaction than shown by the checks.

Summary.—No formation of tumor tissue. The strain of the fungus used for these inoculations had been growing 2½ years on artificial media and had never been known to fruit. It had probably lost its virulence.

GENERAL REMARKS ON INOCULATIONS.

Successful inoculations have been made on lime, pomelo, lemon, tangerine, and *Citrus trifoliata*. Only one trial (five inoculations) was made on oranges, the trees not being available. As knots occur on oranges in the field and as infection took place in the limes inoculated the same day with the same culture, the failure of the experiment was probably due to the fact that the trees were not in good condition or were not of a susceptible variety.

The pedigrees of the cultures used for inoculation have been traced and a comparison of these indicates that a gradual loss of virulence accompanies long-continued cultivation on artificial media, unless the strain is a fruiting one. (See Table IV.) Some of the best results (see lime inoculations (orange strain) of July 20, 1910, p. 59) were obtained with a strain which had been isolated 1½ years, but which had been fruiting vigorously in the various transfers made throughout that period. On the other hand only a comparatively small amount of swelling was produced on tender rapidly growing shoots inoculated with a nonfruiting strain which had been isolated 14⅔ months (see lime inoculations (lime strain) of July 21, 1909, p. 54), and inoculations of vigorous young shoots with a young culture of the same strain 2⅓ years after isolation failed altogether (see lime inoculations (lime strain) of July 20, 1910, p. 61). This strain had been virulent 3½ months after isolation. (See pomelo inoculations of June 23, 1908, p. 47.) Woody tissues are apparently as susceptible to infection as young, rapidly growing ones.

Table IV summarizes the results of the inoculations and various facts of interest regarding the cultures used in making them.

TABLE IV.—*Summary of results of inoculations, classified by host plants.*

LIME INOCULATIONS MADE THROUGH WOUNDS ON TRUNKS OR BRANCHES.

Date and strain.	Culture used for inoculation.				Time under observation.	No. of inoculations.	Percentage of—			Remarks.
	Age.	Medium.	Descended from—	Time since isolation.			Knots.	Swellings.[2]	Failures.	
Dec. 1, 1904, lime.	a, 6 wks	Sterile lime-wood cylinder.	b	2 mos	3½ yrs	9	100	0	0	Trees growing well at time of inoculation; inoculated branches killed in most cases; many witches'-brooms formed.
	b, 2 mos	Beef bouillon	Jamaican knot directly.	do						
Dec. 12, 1905, lime.	11 days	do	Artificial infection; No. 4, Dec. 1, 1904, directly.	11 days	3 yrs	5	60	40	0	Trees had been recently transplanted and were in a dormant state when inoculated. They did not make a very good growth after inoculation.
July 5, 1906, lime.	(?)	do	Artificial infection directly.	(?)	2⅓ yrs	2	0	[3] 100	0	
June 27, 1908, lime.	12 days	Steamed corn meal	Isolation No. 4, Mar. 11, 1908.	3½ mos	1⅓ yrs	12	0	17	83	Trees had been cut back severely and transplanted just before inoculation and all except two (83 per cent) died back to a point below the point of inoculation soon after the experiment began.
Feb. 24, 1909, orange.	4 wks	Potato agar	Isolation No. 2, Jan. 14, 1909.	6 wks	1½ yrs	12	75	0	25	Two of the failures were inoculations on the trunk. All other inoculations were on young though woody shoots. Inoculated shoots stunted and in one case killed. Pycnidia observed on one tumor.
Feb. 25, 1909, lime.	do	do	Isolation No. 4, Mar. 11, 1908.	11½ mos.	1½ yrs	12	0	0	100	Inoculations were made on small stunted trees. They were making little or no growth and some months later several of the branches were dying.
July 21, 1909, lime.	7 wks	do	do	14⅓ mos.	1 yr	3	0	100	0	Three very young tender shoots were inoculated. These shoots grew very rapidly for a few days after inoculation; then grew very little, if at all.

[1] Inoculations made on unwounded bark were unsuccessful, and inoculated leaves fell off before results could be recorded.
[2] Tumor tissue produced, but not in sufficient quantity to be termed a knot.
[3] Slight.

TABLE IV.—*Summary of results of inoculations, classified by host plants*—Continued.

LIME INOCULATIONS MADE THROUGH WOUNDS ON TRUNKS OR BRANCHES—Continued.

Date and strain.	Culture used for inoculation.				Time under observation.	No. of inoculations.	Percentage of—			Remarks.
	Age.	Medium.	Descended from—	Time since isolation.			Knots.	Swellings.	Failures.	
July 21, 1909, orange, spores.	6 days[1]	Steamed potato	Isolation No. 4, Jan. 14, 1909.	6 mos.	23 days to 1 yr. 5 mos.	8	63	37	0	Five fairly young and three very young tender shoots were inoculated. Four of the former formed knots and the fifth was removed at the end of 23 days for sections. Of the three very tender shoots one formed a knot, one was broken off soon after inoculation, and the third was under observation only a month (label lost at time of removal to new greenhouse). Shoots continued to grow rapidly for some days after inoculation. Knots produced on all which were under observation for more than a month. Pycnidia appeared on six of the inoculated shoots. In five cases the portion of the branch beyond the knot died.
July 29, 1909, lime.	7 days	do	Artificial infection directly.	7 days	22 days to 1 yr.	2	0	100	0	Very young tender shoots were inoculated. One was under observation only 22 days (label lost on removal to new hothouse); but slight swelling was shown in 15 days; mature pycnidia and spermagonia on one of the inoculations in 22 days.
July 29, 1909, orange.	do	do	Natural infection directly.	do	22 to 30 days	2	0	100	0	Very tender shoots were inoculated. One was cut off for sections in 1 month; the other was under observation only 22 days (label lost on removal to new hothouse). Pycnidia appeared in great numbers on one in two weeks; on the other in three weeks.
July 20, 1910, orange, spores.	9 days[1]	do	Isolation No. 4 Jan. 14, 1909.	1½ yrs.	11 mos.	[2]5	100	0	0	Tree was very thrifty, making an unusually good growth when inoculated. Two of the inoculations were made on very young tender shoots which continued to elongate rapidly for at least two weeks thereafter; two were made on young but woody shoots; a fifth was made on a branch 5 mm. in diameter. The woody shoots and the branch had probably ceased to grow prior to the time of inoculation. Pycnidia appeared on four within two and four weeks. A vigorously fruit-

									ing strain was isolated from one of the knots. Three infected branches were dead and another was dying in 11 months.
July 20, 1910, lime.	...do.....	.....do..................	Isolation No. 4, Mar. 11, 1908.	2½ yrs...	5 mos.........	3	0	0	100	The inoculated shoots were 2 to 4 mm. in diameter and continued to be vigorous and to grow well after the inoculation, probably owing to loss of virulence of the fungus.

POMELO INOCULATIONS MADE THROUGH WOUNDS ON BRANCHES.

July 5, 1906, lime.	(?)......	Beef bouillon..........	Artificial infection directly.	(?)......	2½ to 3½ yrs....	4	23	50	25	Trees were not growing well at time of inoculation; had been set out but a short time.
June 23, 1908, lime.	8 days...	Steamed corn meal....	Isolation No. 4, Mar. 11, 1908.	3½ mos..	1½ yrs..........	11	55	36	9	Trees were not growing well when inoculated.
July 21, 1909, orange, spores.	6 days[1]..	Steamed potato.......	Isolation No. 4, Jan. 14, 1909.	6 mos...	1 mo..........	2	0	50	50	Young, but rather woody, shoots were inoculated. Shoots grew rapidly for a few days after inoculation; under observation only one month (labels lost during removal to new hothouse). Pycnidia were produced on one of the inoculated shoots.
July 29, 1909, lime.	7 days...	.....do..................	Artificial infection directly.	7 days...	1 yr...........	2	100	0	0	Young, rapidly growing shoots were inoculated. In one case the inoculated branch was killed and covered with pycnidia.
July 29, 1909, orange.	...do.....	.....do..................	Natural infection directly.	...do.....	.....do.........	2	100	0	0	Very tender, rapidly growing shoots were inoculated; infected shoots stunted.

LEMON INOCULATIONS MADE THROUGH WOUNDS ON TRUNK OR BRANCHES.

July 5, 1906, lime.	(?)......	Beef bouillon..........	Artificial infection directly.	(?)......	2½ yrs.........	7	0	0	100	Four of the inoculations were on small trees making little growth when inoculated; three were on a seedling lemon 8 to 10 inches high, which was in very good condition and growing rapidly.
June 23, 1908, lime.	8 days...	Steamed corn meal....	Isolation No. 4, Mar. 11, 1908.	3½ mos..	14 mos........	13	0	0	100	Trees were not growing well when inoculated.
July, 1908, lime.		Bits of young lime knot grafted into wounds.			2½ yrs.........	3	100	0	0	A very vigorous tree a few years old. American Wonder variety.

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[1] Fruiting abundantly.

[2] A sixth inoculation was made, but the branch was broken off accidentally three days later.

TABLE IV.—*Summary of results of inoculations, classified by host plants*—Continued.

Date and strain.	Culture used for inoculation.				Time under observation.	No. of inoculations.	Percentage of—			Remarks.
	Age.	Medium.	Descended from—	Time since isolation.			Knots.	Swellings.	Failures.	
CITRUS TRIFOLIATA INOCULATIONS MADE THROUGH WOUNDS ON BRANCHES.										
July 5, 1906, lime.	(?)......	Beef bouillon..........	Artificial infection directly.	(?)......	2½ to 4 yrs.....	4	75	25	0	
June 23, 1908, lime.	8 days...	Steamed corn meal....	Isolation No. 4, Mar. 11, 1908.	3½ mos..	3½ mos. to 2 yrs.	6	33⅓	66⅔	0	Trees were making poor growth at time of inoculation. Pycnidia were observed on two of the inoculated shoots.
ORANGE INOCULATIONS MADE THROUGH WOUNDS ON BRANCHES.										
Dec. 12, 1905, lime.	11 days..	Beef bouillon..........	Artificial infection No. 4, Dec. 1, 1904, directly.	11 days..	11 mos........	5	0	[1] 20	80	Trees had just been transplanted and were in a dormant state when inoculated.
TANGERINE INOCULATIONS MADE THROUGH WOUNDS ON BRANCHES.										
July, 1908, lime.		Bits of young lime knot grafted into wounds.			1 yr...........	2	50	50	0	
KUMQUAT INOCULATIONS MADE THROUGH WOUNDS ON TRUNK OR BRANCHES.										
July 5, 1906, lime.	(?)......	Beef bouillon..........	Artificial infection directly.	(?)......	2½ yrs.........	5	0	0	100	
July, 1908, lime.		Bits of young lime knot grafted into wounds.			1 yr...........	3	0	33⅓	66⅔	
July 29, 1909, lime.	7 days...	Steamed potato.......	Artificial infection directly.	7 days...	22 days........	2	0	0	100	Young, slightly woody, shoots were inoculated; under observation only 22 days (labels lost on removal to new hothouse).
July 29, 1909, orange.	...do.....	.....do................	Natural infection directly.	...do.....	.....do.........	2	0	0	100	Do.

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[1] Very slight.

INOCULATIONS ON RAW FRUITS (LIME AND ORANGE STRAINS).

Inoculations on lemons.—Ripe lemons which had been soaked 15 to 20 minutes in $HgCl_2$ (1 to 1,000) and then rinsed in distilled water were inoculated by inserting bits of mycelium or spores under the skin. Both lime and orange strains of the fungus were used. The lemons were then placed under a dry bell jar. In three days the inoculated area was soft and slightly browned. The diseased area spread rapidly until the fruit was softened throughout and the entire surface discolored. The rind became black ultimately and was coated with grayish white mycelium. Within a month the lemon inoculated with spores of the fruiting orange strain was covered with a thin stroma filled with pycnidia discharging whitish to yellowish masses of spores, many of which were germinating. The majority of the spores were continuous and colorless, but many were yellowish and there were also numbers of one to five celled spores. (Pl. VIII, fig. 2.) A few days later a few of the brown septate bodies previously described (p. 16) were observed.

Repetitions of the experiment gave similar results. Checks under the same bell jar remained sound.

For comparison, inoculations were made with a Diplodia found fruiting on a dead branch of pomelo bearing many pycnidia of *Sphaeropsis tumefaciens.* (See inoculation No. 121 (pomelo), July 29, 1909, lime strain, p. 58.) The effects produced by the two fungi are very similar and resemble the black-rot recently described by Pole Evans,[1] except that in the latter the lemons become distinctly sticky and there is a greenish brown exudate wherever they come in contact with anything, phenomena wholly lacking in the inoculations previously described.

Inoculations on apples.—Rather green apples were inoculated by inserting bits of mycelium or spores under the skin (both lime and orange strains were used). They were then placed under a dry bell jar. In four days there was a brown rotted area 2 to 2.5 cm. in diameter. At this stage the softening did not extend beyond the discoloration, but subsequently it advanced more rapidly than the browning. In eight days the apples were softened throughout, but, with the exception of one which was just beginning to wither slightly, they had retained their shape perfectly. In 12 days mature pycnidia were present on the apple inoculated with the fruiting orange strain. The epidermis finally became almost entirely black and somewhat shriveled. Seventeen days after inoculation many of the brown septate bodies (see p. 16) were observed. (Pl. VIII, fig. 5.) These were much less common three weeks later. (Under observation five weeks.)

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[1] Evans, I. B. Pole. On the Structure and Life History of Diplodia Natalensis N. Sp. Science Bulletin No. 4, Transvaal Dept. of Agriculture, 1910.

In another set of inoculations the apples, though soft-rotted throughout, did not begin to shrivel for over two weeks. Although pycnidia were present in great numbers only a few contained spores. These apples were under observation nearly four months.

Apples inoculated with the Diplodia (see inoculations on lemons) rotted much more quickly, but otherwise behaved similarly to the above. This Diplodia resembles *Diplodia natalensis* very closely, but the spores are wholly unlike those of *Sphaeropsis tumefaciens*, even when immature.

Inoculations on pomelos.—Inoculations were also made on very young green pomelos, about 2.5 cm. in diameter, still on the trees. The culture used was a 9-day-old potato culture which was fruiting abundantly. There were no signs of disease in three months.

SUMMARY.

1. From knots on lime and orange trees received from Jamaica a fungus, *Sphaeropsis tumefaciens* Hedges, has been isolated which reproduces the knots when sound trees are inoculated with pure cultures of it. Small knots have also been obtained on pomelo, lemon, *Citrus trifoliata*, and tangerine. From these artificially produced knots the fungus has been again isolated and with it successful inoculations on sound trees have been made.

2. The fungus penetrates the tissues far beyond the original point of infection (see description of Tree II, inoculations of December 1, 1904, p. 42) and a badly infected tree is a mass of tumors, sometimes so close together that one can not put a finger between them. On the other hand, there may be considerable distance between two secondary tumors (1½ feet in one case observed, see p. 42) with no external evidence of the fungus, but microscopical examination reveals its presence in small quantities throughout the intervening portion of the stem. This important fact should be borne in mind in pruning for the purpose of eradicating the disease.

3. An abnormal number of new shoots often grow from the knots, forming a witches'-broom. This is characteristic of the disease under favorable conditions.

4. Ultimately that portion of the branch above the knot dies.

5. The mycelium may occur in any or all of the tissues of the stem, producing black areas if present in abundance.

6. Pycnidia may or may not be produced. The Jamaican lime strain has, up to this time, fruited rarely, pycnidia having been observed only in a few very old cultures, and a small number of artificial infections on the hosts (lime, pomelo, and *Citrus trifoliata*). A vigorously

fruiting orange strain has arisen, however, from cultures grown from germinating spores in plates poured from pycnidia in a 6-months-old corn-meal culture. Another orange strain isolated later from the same lot of knots has never, to the writers' knowledge, produced pycnidia in culture media, although it has produced them on lime shoots (see inoculations of July 29, 1909, p. 58). A second vigorously fruiting orange strain has been isolated from one of the knots produced by the inoculations of July 20, 1910.

7. Spermagonia occur both on the host and in cultures.

8. Chlamydospores are often present in abundance in old cultures, but have never been observed on the host.

9. No perithecia or conidia have ever been observed.

10. A stroma is produced on many media but not upon the host.

11. The fungus is easily isolated by ordinary mycological methods and grows well on a large variety of media.

12. The fungus liquefies gelatin, partially or entirely digests casein (see milk cultures, p. 32), and has a strong diastasic action. Optimum temperature about 30° C.

13. The fungus can live for some years in the host. It has been isolated from secondary knots four years and eight months after the tree was inoculated and one year after it has been cut down and brought into the laboratory.

14. Affected limbs should be removed, care being taken to cut them off well below the lowest knot (see "Summary," par. 2). Badly diseased trees should be rooted out and burned, that they may not prove a source of infection to sound trees through the dissemination of the fungous spores. Great care should be taken to select only sound trees for grafting purposes. The recent discovery of this or a similar disease in Florida should put growers in the United States on their guard against the spread in this country of a new menace to citrus fruits.

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A KNOT OF CITRUS TREES CAUSED BY SPHAEROPSIS TUMEFACIENS.

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